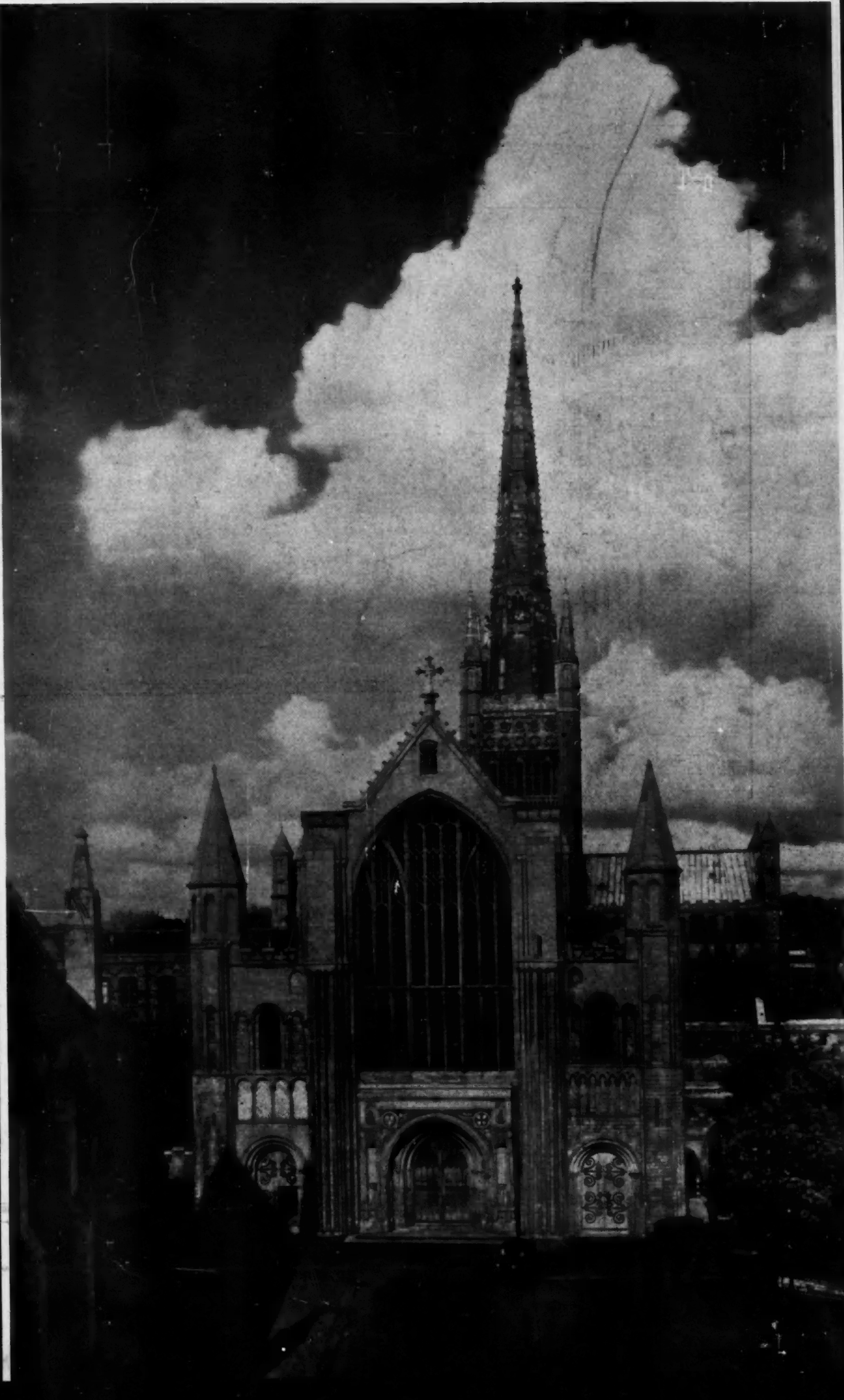
DISCOVERY

THE MAGAZINE OF SCIENTIFIC PROGRESS

SEPTEMBER 1961 2/6

Presidents of the
British Association
for the Advancement
of Science since 1951



23rd ANNUAL MEETING IN
ORWICH, AUGUST 30—
EPTEMBER 6, 1961

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DISCOVERY

VOLUME XXII SEPTEMBER 1961 NUMBER 9

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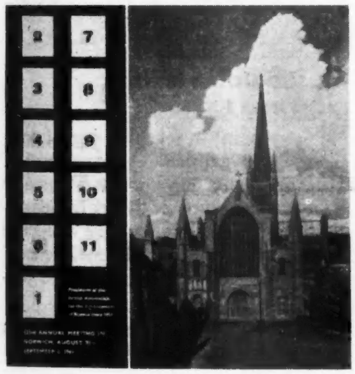


Norwich Cathedral, in the shadow of which the British Association for the Advancement of Science holds its 123rd Annual Meeting, August 30-September 6. Presidents of the Association shown are:

1. 1951 H.R.H. The Duke of Edinburgh
2. 1952 Prof. A. V. Hill
3. 1953 Sir Edward Appleton
4. 1954 Lord Adrian
5. 1955 Sir Robert Robinson
6. 1956 Sir Raymond Priestley
7. 1957 Prof. P. M. S. Blackett
8. 1958 Lord Fleck
9. 1959 Sir James Gray
10. 1960 Sir George Thomson
11. 1961 Sir Wilfrid Le Gros Clark

Reports of the Presidential and some other addresses will appear in the October issue of DISCOVERY.

CONTENTS

THE PROGRESS OF SCIENCE

Science and the crisis

What part has science to play in the recurrent economic crises which face this country and which reached their most alarming climax yet at the end of July? There can be no doubt that it holds an important key to the solution—even if consecutive governments with their political horizons limited to the five years they can be sure of office and responsibility refuse to look beyond hand-to-mouth survival.

It is instructive to find that the National Science Foundation of the U.S., which has over-all responsibility to the President for formulating the wealthiest nation in the world's science policy, has been examining afresh the relationship between national prosperity and scientific endeavour.* It is even more fascinating to find that the Foundation's survey comes to almost exactly the *opposite* conclusions to those inherent in our present government's action in response to the July crisis—which was to give top priority to *cuts* in educational spending and to funds for basic research projects, such as new radio telescopes, one of the few fields in which this country maintains its edge over other industrialised communities and therefore a potential of that most profitable invisible export, "know-how".

The main conclusions of the National Science Foundation's important policy document are these:

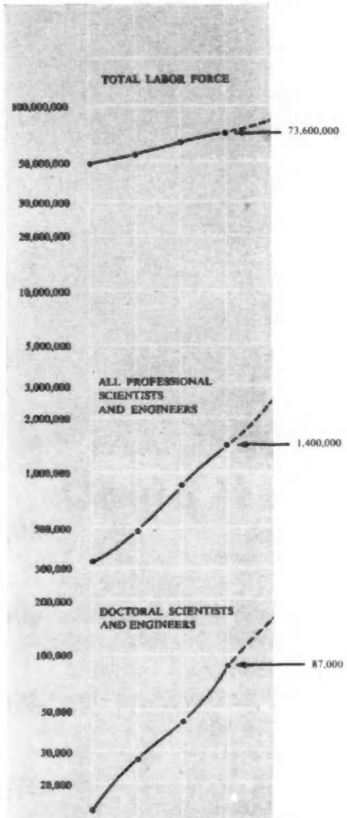
- Scientific talent is a scarce resource that the nation must develop fully to secure its future well-being.
- Steadily increasing numbers of talented young people need to become scientists (simply to maintain the status quo, that is).
- There will be twice as many trained scientists in the U.S. in 1970 only if this trend is maintained.
- *This will require sharply increased dollar investments in science education and basic research.*
- The report analyses science education trends over the past 40 years and projects these trends to the year 1970. The nation's target, it concludes, should be that "every young person who shows the desire and capacity to become a scientist should be ensured the opportunity to do so". Achieving this goal will not deprive other professions of the intellectual leadership required for their expanding needs.
- During the current fiscal year the U.S. allowed a total of about $10 billion* for all engineering and science education and basic and applied research (excluding Defence spending). This represents only 2% of the gross national product of $505 billion (a considerably greater ratio, nevertheless, than is spent in this country). This is not enough.

Simply to maintain the present rate of expansion (see table) the national investment in science and engineering education must increase from $2.1 billion (1961) to $5.5 billion in 1970. The national investment in universities' basic research facilities must increase from $0.9 billion (1961) to $2.7 billion in 1970.

If this is true of a huge country with an expandable population and with a wealth of as-yet untapped natural resources, how much more potent is the argument for a tiny overpopulated island incapable of feeding itself without imports, with virtually no outstanding natural resources and only its capacity to manufacture better things more cheaply—that is more cleverly —than its neighbours as a competitive asset?

**Investing in Scientific Progress 1961-1970*: published by the National Science Foundation, Washington D.C., July 10, 1961.

**Figures stated in U.S. billions i.e. 100,000 × 1 million.*



SCIENTISTS AND ENGINEERS IN THE U.S. LABOUR FORCE

The steady rise in science and engineering degrees has increased the scientific portion of the nation's labour force. The total labour force, now about 74 million, is forecast to grow at about 1.4% per year and to reach 87 million in 1970. The number of professional scientists and engineers has risen more rapidly. At the average rate of 6% per year, it is expected to reach about 2.5 million in 1970. About 87,000 of these professionals now hold the Sc.D. or Ph.D. degrees. The number of these doctoral scientists and engineers is expected to grow at 7% per year and to be about 168,000 by 1970—nearly twice the present number.

Why should machines play games?

Is there any point in teaching digital computers to play games? Apparently, yes. These experiments have made a valuable contribution to computer theory by demonstrating the precise limits of the deductive powers of such "artificial intelligences" and the extent to which they can be programmed to give advice to humans.

This is explained in interim reports on the first three years of a comprehensive study of automata theory sponsored by the U.S. Air Force under the code name *Project Macronet* and carried out by Pennsylvania University's Moore School of Electrical Engineering*.

The way the computer deals with the game "Go", thought to have been invented 4,000 years ago in China, is one of the approaches used by the researchers to investigate machine learning—and by analogy, human learning. It is revealing because a game is a closed universe, having a completely specified set of rules and a fixed goal. A game also "calls on processes of reasoning similar to those involved in any deductive situation".

Games are "frequently good analogies of actual situations involving human beings and their environment—for instance, war, ecology, and finance", according to the

report. As deductive reasoning is closely allied to the memory storage process which computers have shown they can successfully handle, it seemed a reasonable test of automata efficiency to present the machine with a game problem to solve, and let it draw upon past experience to vary its method of solution to improve either the final result or the method of solution itself.

The interesting results obtained from this series of experiments should speed the development of a "plain" language-learning machine, and of a computer programme that will enable anyone who can type to address the machine and likewise get the answer out in "plain" language.

**A Strategic Pattern Recognition Program for the Game "Go"* and *Symbolic Logic and Automata*, published at $2.25 and $1 respectively by the O.T.S., U.S. Department of Commerce, Washington 25, D.C.

Stretching the sound range

Electro-magnetic energy has for the first time been used to amplify energy other than itself. This is the significance of the announcement by the U.S. General Electric Company that its Research Laboratory has succeeded in directly amplifying very-high-frequency sound waves using radio microwaves as the power source.

This is a *maser* technique. Microwave Amplification by Stimulated Emission of Radiation (*maser*) was originally developed for improving reception of low energy radio signals, but has already been extended to the amplification of light waves, giving the *laser* announced earlier this year. The further refinement engineered now by General Electric increases the amplitude of a form of mechanical energy; it is called the phonon *maser* effect—the phonon being one cycle of a sound wave.

Amplification of the phonons is accomplished by stimulating the emission of energy by atoms as these change from a higher to a lower energy level. In both the *maser* and the phonon-*maser* effect, atoms are raised to a high energy first by irradiating or "pumping" them with high frequency electro-magnetic energy. Then, when signal energy of a lower frequency is introduced, stimulated emission of the signal frequency occurs, and, under proper conditions, the stimulated emission may be strong enough to produce amplification of the introduced signal.

The pumping of a sound signal has been successfully achieved with short pulses of VHF sound (at 9.3 kilo-megacycles), using a ruby crystal as in the *laser*. The crystal is formed of alumina, Al_2O_3, with chromium ions introduced as the impurity. When the ruby crystal is placed in a magnetic field the electrons of the chromium ions, acting as tiny magnets, tend to line up with the field and then produce characteristic energy levels depending on the degree of alignment with the field.

The lowest energy level, into which most of the electrons fall, can be pumped up by absorbing energy at a resonant frequency which is determined by the magnetic field strength and the crystal characteristics. In the phonon-*maser*, the electrons are raised two levels, using the frequency 23 kilo-megacycles with the ruby crystal held at a temperature of 1.5°K. When the lower frequency signal is introduced, stimulated emission takes place. The amplification so far observed has been 12% per centimetre of ruby.

Quite what use this new development of the stimulated emission principle can be put to is not yet clear. General Electric say they see no immediate commercial value for it.

It does represent a notable advance in solid state physics however, and the technique may prove a useful tool for investigating the role of phonons in nature. It is perhaps misleading to speak of the frequencies that can be amplified by the new effect at present as "sound"; they are in fact far above the range of the human ear, in the further ultrasonic region. If the technique can be adapted to produce an acoustic oscillator, it may be possible to generate ultrasonic waves of greater

frequency, and therefore potency, than anything yet achieved. It has been suggested that with such a tool surgery so delicate that it could remove individual bacteria might be conceivable.

Warning of radioactivity

The Council of the Organisation for European Economic Co-operation (OEEC) to which the U.K. belongs, has established a European system for the supervision of environmental radioactivity and for emergency alerts where an abnormal increase is detected. This may be extended to water-borne contamination later.

The provisions are to cover the small possibility—as occurred in the Windscale incident in 1957—that despite stringent safety measures at atomic energy installations, there may be an accidental discharge of radioactive material into the atmosphere. Three levels of environmental radioactivity are recognised for international reporting to OEEC members: *emergency*—defined as a "nuclear incident or substantial increase in radioactivity entailing regional health hazards"; *pre-emergency*—defined as a "substantial increase in radioactivity of unknown origin or resulting from a minor incident which does not call for local health protection measures"; and, *scientific interest*—defined as an "abnormal increase in radioactivity of purely scientific interest". Only the emergency category of radioactivity will warrant international communication "by the most rapid means".

The European Nuclear Energy Agency (with its headquarters in Vienna) drew up the provisions for warning standards and an alert network.

The Hyrcanian Tiger

If a modern dress Macbeth offered his famous challenge to do battle with the rugged Russian Bear or the Hyrcanian Tiger rather than face the ghost of Banquo, should we be right to think he was pulling a fast one? Does the Hyrcanian Tiger, fabulous for its ferocity since Roman times, still exist along the shores of the Caspian?

To find this out a group of Oxford University biologists is to explore the high passes of the Elburz mountains south of the Caspian this autumn. The expedition is also making collections for a number of institutions—plants for Edinburgh University, bulbs for the Royal Horticultural Society, bird skins for the Natural History department of the British Museum, and various items for the two sponsoring bodies, the Oxford University Museum and the University of Teheran (which is also to be represented on the expedition).

Northern Rhodesian perfume

The Tropical Products Institute (T.P.I.) of the DSIR is playing a big part in the economic and commercial development of the plant *Aeolanthus gamwelliae*, whose flowers produce an oil which may give Northern Rhodesia a share in the world's perfumery trade. One British soap manufacturer has bought trial consignments of the oil for use in toilet preparations. Its main use is expected to be in the manufacture of bath-soap—but this depends upon being able to maintain the quality of the perfume oil, called Nindi, at low production cost.

Two English sisters, the Misses Gamwell, after whom the flower is named, discovered the plant in Northern Rhodesia in the thirties. Since then the oil has been distilled from it spasmodically by some farmers in the Abercorn region. Meanwhile analysis at the T.P.I. (then the Imperial Institute) in England showed that the plant contains an unusually high concentration of the valuable perfumery constituent, geraniol.

Last year a staff member of the T.P.I. proposed to the Northern Rhodesian authorities and the farmers there that cultivation of *Aeolanthus gamwelliae* was a good commercial proposition. It grows in the isolated Northern Province where transport is costly and difficult and where a new cash crop with a high price-to-bulk ratio is particularly welcome. In general, Northern Rhodesia is economically and politically at a disadvantage vis-à-vis its larger and richer southern neighbour.

A firm of still manufacturers, in consultation with the T.P.I., has designed a small Nindioil distillation unit, and two such units are shortly to be installed in the territory and should yield hundredweight quantities. The cohobation technique of distilling is used in this design and it is still not clear why this method produces greater oil yields than the older methods formerly in use by Rhodesian farmers. This may be the key to whether or not Nindi oil can be manufactured cheaply in commercially useful amounts.

First dendroglyphs

Discovery of the first authentic Maori dendroglyphs (tree carvings) was announced in New Zealand this summer. The find was actually made by two New Zealand amateur archaeologists in September, 1959, but has been kept a closely guarded secret since then until full authentication and examination was complete.

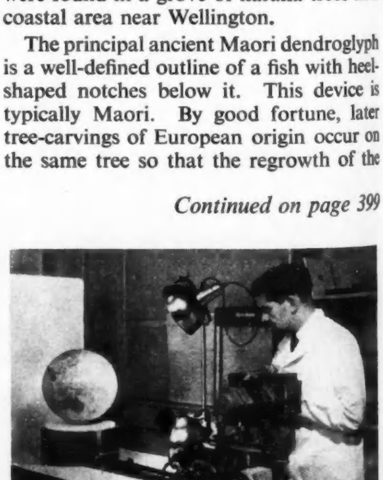
Now the Dominion Museum ethnologist, Dr T. Barrow, has declared them to be the first authentic tree carvings of Maori origin to be placed on record, and they certainly belong to the early period of Maori culture in New Zealand. Such a find has been long awaited and is of major importance in the study and dating of the early inhabitation of New Zealand. They were found in a grove of karaka trees in a coastal area near Wellington.

The principal ancient Maori dendroglyph is a well-defined outline of a fish with heel-shaped notches below it. This device is typically Maori. By good fortune, later tree-carvings of European origin occur on the same tree so that the regrowth of the

Continued on page 399

SEEING FROM ALL SIDES AT ONCE

An all-round view (left) of Mr F. Fox, designer of the new Periphery Camera (right) developed by the Thornton Research Centre of Shell. It is claimed to have much improved resolution at a variety of focal lengths, and can photograph "in the round" objects ranging in size from revolver bullets to motor car tyres.



SPACE RESEARCH

ANGELA CROOME

Life on Venus?

The planet Venus reached the point in its orbit which brings it nearest to the Earth and therefore to its most favourable condition for observation during the past quarter. It will not come so close again for 18 months. Venutian studies, previously a rather deprived field, have received a shot in the arm from the progress of space research. It is the most promising target for manned spaceships after the Moon, and it seems to offer a pleasanter environment.

Knowledge of the planet is so limited that this cannot be stated with any certainty. It may prove quite the contrary, for the planet's surface has never been seen and may be entirely covered by ocean; moreover the "clouds" that permanently shield the surface from earthly eyes appear to contain high concentrations of carbon dioxide, with an atmosphere poisonous to human lungs.

Laboratories all over the world have been making a special effort to settle some of these questions this summer. Radar techniques have been principally employed, since radio waves in contrast to light waves can penetrate the dense clouds that lie between us and the planetary surface. Even at its closest, about 25 million miles away, Venus lies at the very extreme range of the world's most powerful radar, so that the following preliminary results must be considered tentative.

Soviet scientists operating their instruments in the middle of the decimetre waveband with 250 megawatts-per-steradian power, conclude that the speed of rotation of Venus is between 9 and 11 earthly days. If the axis of rotation is parallel to that of the Earth the rotation period is close to 11 days. American work with the Goldstone 84-foot radar situated in California suggests that the Venutian surface is exceedingly smooth, as might be the case if it was covered with water.

The most expensive experiment and potentially the most interesting in this year's series, was the Soviet attempt to gain direct information on the planet's environment from a deep space probe passing within a few hundred thousand miles of the planet's surface. This effort unhappily proved abortive due to the early collapse of the probe's radio system.

The most daring Venus experiment this year is yet to come. It will be attempted this month by the young French astronomer and balloonist, Dr Adouin Dollfus, of Meudon Observatory, Paris. He hopes to ride an hermetically sealed fibreglass gondola pulled aloft by 25 extra-large met-balloons to the edge of space, to make spectroscopic measurements of the Venus atmosphere. This should determine whether the large amount of water vapour observed in the Venus spectrum by ground-level instruments comes from the Earth's own atmosphere or resides in the atmosphere of the distant planet.

If Dollfus can reach to 20km. high he will be above all but 0.01% of the water vapour in the Earth's atmosphere and separation of the components should be straightforward and revealing. It may even be possible to indicate whether water vapour in the Venus spectrum comes from the planet's surrounding cloud or from the planet's surface.

Dr Dollfus attempted this experiment with an even more dicey balloon system at the last Venus close approach and nearly succeeded, so he has confidence that he may pull off this rather alarming project this time. He has had to postpone it from the more favourable month of June because of the ban on unconventional flying activities at the time of the Algerian crisis.

New U.S. moon equipment

An ultra-compact *nuclear power plant* that can be assembled on Earth, transported by rocket and continuously operated on the Moon for two years by remote control without other attention is described by a recent U.S. Atomic Energy Commission report as capable of being constructed at the present time "with little or no development". It would be capable of providing power for spacecraft refuelling, TV relays, and stellar and physical laboratories on the Moon.

The system consists of a fast reactor using mercury running in direct cycle with a mercury-vapour turbine. The mercury vapour is condensed and the hydrogen (for the generator cooling system) is cooled in wing radiators. These wing radiators are the unique feature of the design. They are considered to be the only feasible means at present known for removing the high temperatures generated in a fast reactor operating in a vacuum such as the lunar environment. The four radiators of this special design envisaged for the lunar reactor are capable of being folded into the cylindrical shell of the main power package for the rocket voyage to the Moon.

A *moonlight photodetector* with a sensing surface smaller than a pinhead devised by two NASA scientists at the Goddard Space Flight Centre is being produced by the research group of IBM. It is the nub of a new, more sensitive system for determining where a space vehicle's instruments are pointing and thereby helping to evaluate their data. This is done by amplifying and then electrically coding the flashes of light that fall on the sensor from Sun or Moon as a satellite spins. Its range of sensitivity is enormous, since it is capable of registering brief glimpses of the Moon (estimated at one-ten-millionth of the brightness of sunlight), as well as withstanding continuous exposure to direct sunshine. This is made possible by having a tiny semi-conductor wafer (silicon) coated with a layer of liquid electrolyte (sulphuric acid). The sulphuric acid remains stable over a wide range of temperatures and at the same time barely absorbs light falling on it, being a liquid.

Most comprehensive upper ionosphere study

A research report has been published by NASA (the U.S. National Aeronautics and Space Administration) on the ionosphere research satellite, *Explorer VIII*, which had an active life of two months last autumn (during which period it produced 500 pieces of information per second) and has proved one of the most useful satellites yet launched. The orbital path of the satellite lay between 275 and 1450 miles high so making it a probe of the upper ionosphere with which eight out of its ten experiments were concerned. Results however, are not only of prime interest to ionospheric physicists and to all concerned with radio communication; *Explorer VIII* has yielded bonus results of importance in other fields including that of space engineering.

The five main **ionospheric experiments** were entirely new. Four of them depended on techniques involving orbiting sensors which function as vacuum tubes without glass envelopes. These vacuum tubes differ significantly from those in a television set only insofar as a vacuum seal is not necessary since the near vacuum of space provides this naturally.

The fifth basic ionospheric experiment measured the electrons in the region by registering the amount of detuning they produced on an antenna. Between them these experiments counted the number of electrons (negatively charged particles) and positive ions in the upper ionosphere.

It has been found, on the whole, that the upper ionosphere is homogeneous—that is, it does not contain nearly as many disturbed regions as the lower ionosphere.

Continued on page 399

A BRIDGE FROM ARTS TO SCIENCE

A. D. PETERSON

- *The two intellectual disciplines—"scientific method" and "sympathetic insight"—should be balanced within the student rather than within the student body.*
- *Lack of training in the language of science, particularly mathematics, makes this impossible for nearly all Arts men.*
- *There is, however, a reserve of mathematics teachers which could be tapped by sixth-form reorganisation.*

With so many new Universities on the stocks people are naturally concerned about what they are going to teach. It is easy to see that as an industrial nation in the second half of this century we shall need a great many more scientists and technologists; and almost equally easy to argue that if we are to preserve our cultural heritage, or whatever comfortable phrase one likes to use, this expansion must be balanced by an increased provision of liberal education on the Arts side. But then the creeping doubt sets in. Are we sure that we are not producing too many frustrated graduates, of perhaps not quite the highest academic quality, in pure History, English or Languages already?

It is not surprising, therefore, that some have wondered, rather wistfully, whether it would not be possible, even at the University, to produce this balance within the individual rather than within the student body, by providing more degree courses which combine both Science and Arts.

Function of the University

The function of the University has sometimes been described as the advancement and transmission of knowledge. Not everybody in the University, not even all the teachers, can genuinely be concerned in the advancement of knowledge. This is particularly clear if we remember that the transmission of knowledge has got to be done to young men and women who will not be able to absorb the knowledge efficiently, if none of their teachers has the time or the will to be concerned with them as people.

For those scholars who are primarily concerned with the advancement of knowledge, it seems probable that a formal combination of interest in Science and Arts would be out of place. But when we come to those whose function is to absorb and transmit the whole of our culture, the argument for

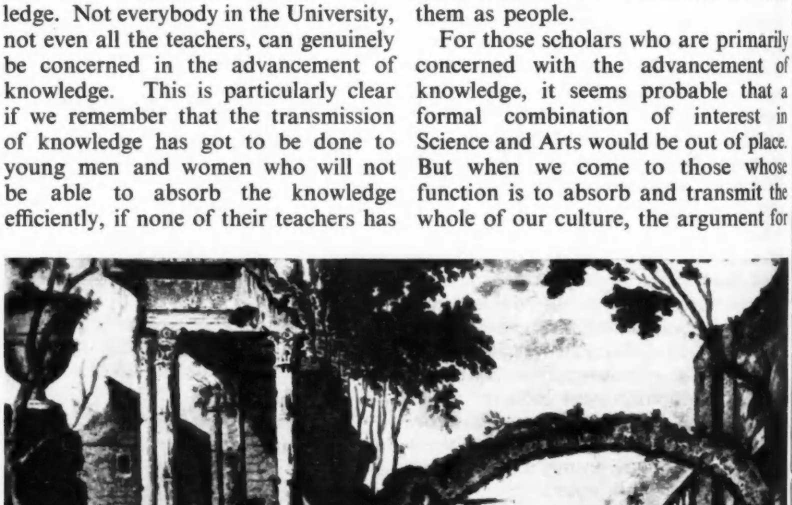


FIG. 1. *Astronomy as a fashionable pastime. Science and Arts in the Eighteenth Century were all part of polite learning.*

Mr Peterson is Director of the University of Oxford Department of Education.

FIG. 2. *Tigani harbour on the island of Samos, now renamed Pythagorion. If the application of mathematics to phenomena is the key to scientific method this might be regarded as the birthplace of modern science. (A "still" from the teaching film "Earth & Sky".)*

combining Science and Arts in a single individual rather than a student body becomes worth considering.

For the great body of undergraduates who leave the University after taking their first degree and go into industry, commerce, the Church, the Civil Service or the B.B.C., the day after finals is the end of their academic career. They are urged by notices in the Students Union or College Lodge to hurry off to the University Book Shop and sell their books. What then is the function of the University in transmitting knowledge to them?

It is of course valuable if they can be brought into brief contact through their teachers with the temporary "frontiers of knowledge"; and more valuable still if they can have helped for a moment, however humbly, in pushing them back. To some this may happen. But it is the function of transmission which is of primary interest to them, and this should be considered under two heads :

(*a*) The development of the individual's capacity to interpret intellectually his own experience, and so to play a part in reinterpreting our common experience to the next generation. This is important to him as a human being. It is also an important element in the transmission of knowledge, since it is not only professional teachers who pass on the culture of a society from one generation to the next.

(*b*) The development of the individual's "map of knowledge". By this I mean his more or less passive awareness of the currently accepted conclusions about the nature of the world. This also is important to him both as a human being and as an agent in the transmission of knowledge.

The Methods of Science and Art

How relevant, then, to those for whom this is the function of the University, is C. P. Snow's analysis of the two cultures? Is it true that an "Arts man" has a maimed capacity to interpret his own experience if he does not understand scientific method, or that he has an inadequate map of knowledge if he is unaware of scientific conclusions? What does the "Scientist" lose by not having cultivated the Arts?

The first question we must ask is whether there really is such a thing as the scientific method, different in essence from the method which is used in the study, at University level, of the Arts. It is sometimes glibly assumed that the method of scientific discovery and the method of transmission of scientific knowledge are the same. But we should consider whether there are genuine differences between the studies of Science and the Arts, under the separate aspects of advancement and transmission.

As a "non-scientist" I suppose that the process of scientific discovery is something like this. The first step is a flash of imaginative intuition—that *this* and not some accepted theory or lack of theory is the better explanation of the phenomena; very often such a flash derives from the sudden realisation of an interconnexion between things only partially understood and previously regarded as anomalous or disconnected. There seems to be no essential difference here between the methods of the scientist, the poet, the literary critic or the historian.

The next stage for the scientist is presumably the design of experiments which might possibly strengthen or falsify his hypothesis; and in most cases nowadays the design of these experiments involves the application of mathematics. It is here that his method seems to me to diverge sharply from that of the historian or literary critic, first because of the use of mathematics and second because he can design experiments which can be repeated under controlled conditions.

While the Arts man, in coming to a

conclusion based upon empirical evidence, is not accustomed to using either of these techniques, he does use a method which is not open to the scientist. This I would call sympathetic insight. He can, because both subject and object are phases of human consciousness, try to feel himself into the mind of Robespierre or Byron or even, I would suggest, of Heathcliff, in a way that the biologist cannot feel himself into the mind of a frog.

The differences in these two methods seem significant enough to justify common use of the term "scientific method" for one of them. But does it matter if the graduate who is going to use his trained mind in interpreting all sorts of experience outside the academic field is accustomed to using only one of these two main methods? I think it does. One has only to think of a general or the chairman of a shipbuilding firm who declines to pay any attention to operational research on the ground that anyone can lie with figures and that he knows better by instinct, or alternatively who accepts a proposal which is logistically impeccable, but will not work because it has been calculated without any real insight into the reactions of the people it will affect.

We may, of course, believe that the required combination of respect for the logic of the figures with humane insight is either a "gift" or is learnt from practical "experience", but it has nothing to do with University education. If we do believe this, I suggest we must abandon the view that higher education produces the "trained mind". But if we do not abandon it, we must surely accept that it is an advantage to be skilled in both methods.

It still does not follow, however, that in order to be skilled in both methods we must have been educated in both. The Cambridge University Appointments Board, realising in 1945 that a large proportion of future undergraduates would go into industry rather than academic life, produced a report on "University Education and Business," which contained these words: "The teaching of the University develops a mental attitude of real value, irrespective of the subject studied. This is not so much the attitude of the narrow specialist, but rather of the man who having specialised in one subject has learnt a respect for *and the method of* (my italics) approaching other specialities."

The Crowther report makes much the same claim for concentrated specialisation in a narrow field at school. It is indeed the classic defence used in the middle of the nineteenth century to defend the classics. But is it true?

If we can be sure that the man who has specialised in languages and literature from the age of 15 to 21 will have a mind just as well trained in scientific method as he who has specialised in Physics and Mathematics, then there is no need to worry. It is very difficult to find easily assessable evidence either for or against this proposition and, as far as I have been able to ascertain, those who make it never attempt to produce any. On the whole I think common sense is against it, and certainly educational theory is.

It is of course possible to teach an intelligent man *about* scientific method, rather than to teach him in such a way that he actually uses the method. It is also much quicker, and if nothing else can be done for lack of time, it is presumably better than nothing. This is probably the justification for a good many "compensatory" courses in "History and Philosophy of Science". But both theory and the weight of experience show that if an intellectual method is to be effectively applied to new and unfamiliar problems it must to some extent have become second nature. For this to happen it must have been used in practice over a considerable time and range, not merely learnt about externally.

Advantages of Training in Both

From this it seems to follow that for the advancement of knowledge or the solution of problems, the fully trained mind will usually be better for having trained in the methods of both the Sciences and the Arts.

When we look at the "map of knowledge" and its transmission, the argument is shorter and simpler, but the conclusion the same. To leave out of our map the interpretation of the world around us which derives from modern science is surely to limit ourselves severely as conscious human beings: and the same is true for the Arts.

It is sometimes argued that Scientists can and do acquaint themselves in the course of their lives with a great deal that history and literature have to offer, without any special provision being made for this in Higher Education; and that the failure of the Arts man to do the same in Science is due to lack of will rather than lack of capacity.

To some extent this is probably true of the good scientists, but the position, as between the two disciplines, is far from equal. Arts-educated men are often incapable of extending their map of knowledge to include the findings of science, because they have never been taught the language in which these findings are written.

The Problem of Basic Language

No student enters the University without having spent a good proportion of his school education, at least until the age of 15 on the study of Arts subjects; but a recent survey, carried out by the University Education Society, of the 1960 entry to Oxford revealed that nearly one-third of them had passed no Science subject even at "O" level, except Mathematics. And "O" level Mathematics is not the Mathematics which the modern scientist uses. Indeed it normally contains no mathematical ideas or processes which were not familiar before 1640.

For the individual to acquire an adequate knowledge of current scientific findings to complete his map, it may not be necessary for him to use the method which scientists use in making new discoveries, any more than the educated man who is aware of the main issues in the American Civil War need be trained in the research techniques of the historian; but it is necessary for him to understand the language and the basic concepts through which the findings of Science are communicated.

It is, I suggest, this failure to learn the basic scientific language that makes communication between the two cultures so difficult. If inter-communication is to be encouraged the two requirements are a greater degree of common "language" and the abandonment of a rigid division in adolescence into mutually suspicious "sides".

If then combined Science and Arts courses should be taught, where should this be done? In the last years of school or at the University? As far as England is concerned one would hope that the answer might be both, but it is the University that matters most. It is possible to combine Science and Arts subjects at Advanced Level in the Sixth Form but in fact not more than 3% of boys and 10% of girls do, even counting Mathematics as a Science subject. There may be a variety of reasons for this, but the decisive one is probably that a combination of Science and Arts subjects would be unacceptable to most University faculties.

Since University entrance requirements control the sixth form curriculum, it is from the University that any change must come. But one of the factors which inhibits Universities from starting combined courses is that pupils coming up from school are almost certain to be inadequately qualified on one side or the other. Thus the great difficulty facing the first proposal for a combined Science and Arts Tripos at Cambridge was that it would have involved teaching Nuclear Physics to students whose Mathematics stopped at 1640 and had been dropped from their course at the age of 15.

Similarly it was pointed out at the recent symposium on the History of Science at Oxford that virtually no undergraduate reached the University having studied both History and Science in the Sixth Form. Nevertheless it is clearly the Universities which must take the lead now, and there are signs that this is happening.

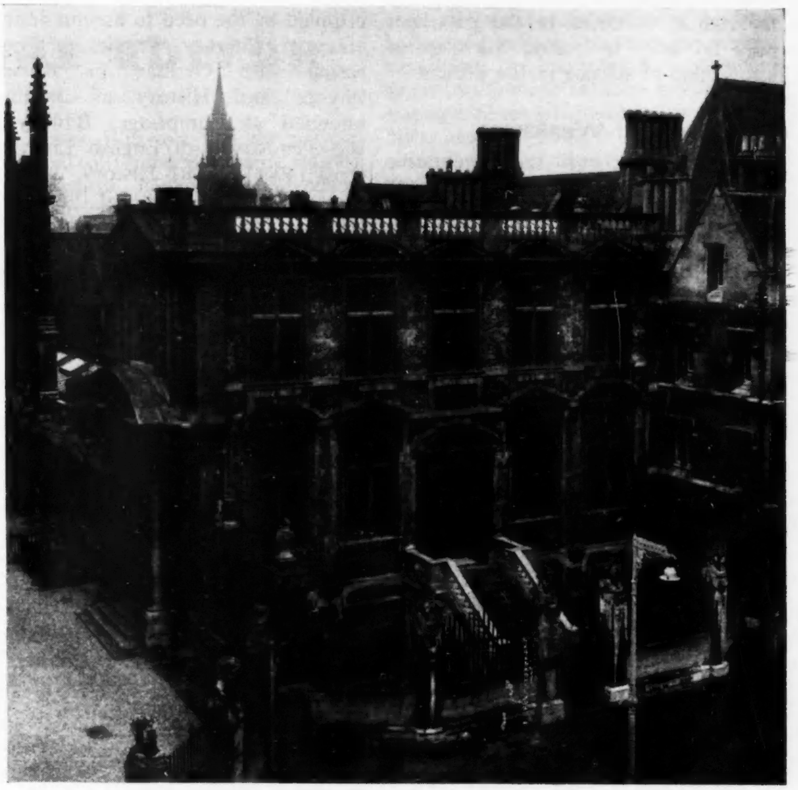


FIG. 3. *Museum of the History of Science at Oxford. Built, possibly to Wren's designs, in 1683, it housed the University's first school of Natural History and, in the basement, a laboratory and "Chymical Librarie". Today it houses collections illustrating the development of scientific thought and equipment.*

Combined Arts and Science Courses

Universities have for a long time offered some courses which combined Arts and Sciences—for instance, Geography and Architecture, but these remain specialist disciplines in their own right; the newer experiments, either tried or proposed, have involved a combination of "subjects" from the two sides which are also studied in isolation. Of these it is possible to distinguish two types: there are the general honours degrees including a Science or an Arts subject sometimes as a subsidiary, and there are the "double honours" degrees. The first type is best represented by the North Staffordshire degree course, in which, after a "foundation year" in which the student samples a wide variety of disciplines, he chooses two major and two subsidiaries, one of which must always be taken from each of the two disciplines.

The London B.Sc (Econ.) also permits the taking of Mathematics as one subject in a degree which would generally be regarded as on the Arts side, and the new general degree college proposed as an extension of Nottingham University, clearly envisages degrees which will combine the two disciplines in this sort of way.

"Double honours" bridging the gap have not yet made such headway. It is possible to combine Physics and Philosophy at Leeds, though not in equal proportions. The original proposal at Cambridge to link History with Nuclear Physics was turned down, and the successor proposals to make the science element either biological or a wide general study of the physical sciences seem even less promising. There has been talk at Oxford of a double honours course in Economics and Engineering, E. and E. as a rival to P.P.E., but nothing has yet transpired.

Finally, there are what one might call the cultural/scientific courses, of which the most favoured is the History of Science. This can be taken at some Universities as an optional subject in a science first degree and also as a postgraduate diploma. It is a valuable corrective to the neglect of this element in traditional history courses, and would be an admirable special study for those who were already experienced both in History and Science; but as a bridging of the gap it is surely too historical and not sufficiently scientific. It can give the Arts-educated man some external acquaintance with scientific

method as practised in the past, but may do little to extend his map of knowledge of science in the present.

The Essential Weakness

Which, then, of these tentative efforts is worth pursuing further? Their very diffidence discloses the essential weakness, that they are too often despairing attempts to find some kind of scientific education which can be undertaken by people with a rusty and rudimentary understanding of Mathematics. It was this lack of Mathematics which really scuppered the first Cambridge plan and which has been the great stumbling block in the I.C.I. transfer courses. Nor is it merely the Physical Sciences in which Mathematics is now essential. No less than nine new developments in medicine have recently been listed which depend on Mathematics. Perhaps we should give up the idea that we can teach modern science effectively to those who are innumerate.

Is the right strategy then to concentrate first on the provision of University courses which include both Mathematics and an Arts subject? There is good precedent for it; there is a desperate national need of more mathematicians in the teaching profession; and no one acquainted with Oxford "Greats" or P.P.E. or the Cambridge Tripos, could say that honours degree courses of more than one subject are not academically reputable.

The Extension of Mathematics Teaching

Having established or extended courses of this kind, we might hope to see the teaching of Mathematics to Sixth Form scholars who are not going to be specialist mathematicians or scientists. Then we might hope to build double honours courses, combining Arts and Science, which were not crippled by the need to assume innumeracy or illiteracy—Physics or Engineering with German or Russian, Physics and History as originally intended at Cambridge, Biology or Bio-chemistry with English Literature (post 1400!) or with History. None of these would be intended for future scholars or specialist teachers, but would they not provide a liberal education for future men of the world?

Two objections are likely to be raised, one educational and the other practical. The first is the charge of incoherence or dispersal of effort. Nobody wants young men, like Stephen Leacock's Canadian undergraduate, to study Turkish, Music and Theology because the lectures in those subjects take place in the same room at 9.0, 10.0 and 11.0 a.m. But there is a relevance between the pairs I have mentioned, particularly if the History of Science is brought in with Physics and History. It is surely just as important a function of higher education to help a student build a coherent picture out of the diverse experiences of the world, as it is to confine the range of his studies to a field so narrow that internal coherence imposes itself.

Nor can one really argue that there would not be time for adequate study in depth within such double courses. Professor Flew has pointed out (*Oxford Magazine*, March 9) that in "Greats" one does two principals in seven terms while North Staffordshire allows nine terms for two principals and two subsidiaries.

The practical objection is a simple one. It is that the shortage of mathematics teachers in schools has already passed the point of no return. Even granted that we cannot hope to get more mathematics teachers unless more Sixth Formers study Mathematics, it is in fact already impossible to expand the teaching of mathematics for lack of staff.

For the advancement of knowledge or the solution of problems, the fully trained mind will usually be better for having trained in the methods of both the Sciences and the Arts.

An Untapped Reserve

A way of breaking this vicious circle must be found and fortunately a way is open. On a recent visit to one of the great Northern Grammar Schools with over 1,000 pupils I found that of the 11 teachers teaching mathematics, only three had specialist mathematics degrees; yet one of these spent more than half his time, eighteen periods a week, coaching six boys for Oxbridge scholarships.

Neither this time allocation nor this concentration on a few "flyers" is unusual. A Ministry of Education Survey made in October, 1958, showed that nearly half the teaching groups for science subjects in Sixth Forms in maintained schools consisted of five or less pupils. Mathematics here counted as a Science subject and was one of those in which the number of small groups was actually greater than this average. There has almost certainly been some change towards larger groups since 1958 but the Oxford University Education Society survey mentioned above reveals again this pattern of small "Scholarship" groups persisting in the 1960 entry to the University: 82% had spent a third year in the Sixth (a figure higher than that found by the Linstead Committee) and during that year had been taught in groups smaller than 10.

The purpose of these concentrated third year groups is usually the winning of Oxbridge scholarships or competition for entry to a favoured faculty. The result of 18 to 20 periods of mathematics in conditions approaching private coaching is that the mathematical knowledge of recent Oxford entrants has been so high that the syllabus of "Maths. Mods." has had to be revised *upwards*.

It is surely worth considering whether this system involves a misuse of our supply of first-class mathematics teachers; and whether, if they were diverted to teaching more sixth-formers at not quite such a degree of intensity, we might avoid the disaster which seems to threaten us. Certainly without an extension of mathematics teaching to those who are not specialist mathematicians, there seems little hope of producing a balance between Science and Arts within the student rather than within the student body.

LETTERS TO THE EDITOR

Expansion or Illusion?

From Dr J. R. Edisbury

Sir:

To me, the least implausible explanation of the paradox so ably expounded by E. G. S. Churchill (July, page 319), is that the apparent galloping expansion of the universe is an optical illusion. Hubble himself was not at all keen to interpret all red-shifts as due entirely to line-of-sight recession; he spoke—almost hopefully—of a possible "new principle of nature" that would remove the need for such complications as recessing factors, and incidentally avoid having to account for (*inter alia*) indefinitely accelerating expansion unaided by any obvious external force.

My diffident hypothesis is that a red-shift is the resultant of two effects: (1) a genuine Doppler shift, D, positive or negative, whose magnitude depends only on line-of-sight velocity; and (2) a pseudo-Doppler effect, ψD, always positive, related only to distance. $\Delta\lambda/\lambda = D + \psi D$. Up to a few kiloparsecs, ψD is negligible. Over the longer reaches of outer space ψD dominates and ultimately swamps D; and as it is proportional to distance it creates the illusion of expansion.

To account for ψD, I postulate a cosmically widespread field, F, which may well be a property of space. F behaves unselectively towards light and other electromagnetic waves *as if* it were a gravitational field of about 10^{-7} c.g.s. unit. What its real nature is I cannot guess—it may be Hubble's "new principle"—but its value could be deduced from Hubble's Constant, of which it is merely a restatement, if only Hubble's Constant were not still uncertain over a 4:1 range (about 75 to 300 km/sec per megaparsec; or—as Hubble would have preferred it—*observationally*, $\Delta\lambda/\lambda = 1/4000$ to $1/1000$ per Mpc). Maybe someday someone will "do an Eddington" and calculate the thing from first principles.

A rough value for F can, however, be deduced simply enough: consider a light-path of one megaparsec, or about 3×10^{24}cm, and take Hubble's Constant as 1/3000 per megaparsec. Then

$$1/3000 = \Delta\lambda/\lambda = 3\times10^{24}\times F/C^2,$$

where C is the velocity of light, 3×10^{10} cm/sec.

$$\therefore F = C^2/3000\times3\times10^{24}$$
$$= 10^{-7} \text{ c.g.s. unit.}$$

If this hypothesis is right the limit to observability is set by faintness rather than by distance *per se*. Expansion, contraction, or pulsation (I'm told that the universe can't stand still for thermodynamic reasons) is everywhere leisurely, with remote nebulae drifting around in much the same way as local ones. And it should be possible in the future to record values of $\Delta\lambda/\lambda$ so much in excess of unity that even Relativity Theory can't keep up—values interpreted not in terms of impossible velocities $>c$, but as due to distances beyond the present apparent confines of the universe.

J. R. EDISBURY

14 Glan Aber Park,
Chester

Re-calculating Pi

Sir:

Referring to your extract in the July, 1961, issue, entitled "Re-calculating *pi*", your statement that mathematicians had shown theoretically that π cannot be worked out is surely evident. But there is no theory about it. It is a hard fact that 180° divided by π radians can never be fully evaluated because of the infinite relationship of circle diameter to circumference.

It puzzles me how, to work π to 10,880 places, it takes 35 million separate calculations. π is a value of degrees, minutes and seconds and however accurate in evaluating this one may be, one can never arrive at a definite answer, but having decided upon a value, then it becomes a matter of simple division to divide the value into 180°. To go to 10,880 places therefore, needs 10,880 sub-calculations of one extended calculation.

At a figure allowance of 15 seconds per place it requires therefore, $10{,}880/4 = 2{,}720$ minutes or $45\frac{1}{3}$ hours. In practice, however, it would not need 15 seconds per place, as with any repetitive action, one quickly learns the "short-cuts", in this case the need not to calculate when the place figure is one previously calculated.

To me this extract is typical of how quite simple and straightforward mathematics is wrongly made to appear clever and difficult; but it does not show any computer in a good light.

N. TAYLOR

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The Green, Harlow, Essex

Use of Colour Filters

Sir:

Mr Firsoff's article in the June issue, on the subject of Colour Filters in visual use with telescopes on planets contains much of interest to the student of this little understood subject. However, an impression might be conveyed that planetary detail not otherwise seen would automatically be rendered visible if appropriate filters are used. This is by no means the case. Competent planetary observers have used efficient filters since the turn of the century, but few indeed would claim to have thus discovered new details visually.

An orange filter for Mars will enable a photographic film to enhance shading contrasts quite considerably, and at the same time make the polar caps almost disappear. The same filter used visually has only a small fraction of this effect because the very peaked nature of the colour sensitivity curve of the eye means that it is substantially monochromatic compared with a panchromatic film.

Filters used visually can thus only have a minor effect with delicate tints or colours of very low saturation. Even this small effect is reduced by the retinal colour fatigue which causes any predominant colour to give rise to severe loss of sensitivity to the appreciation of that colour, while enhancing sensitivity to absent ones.

In discussing colour attenuation by the earth's atmosphere Mr Firsoff compares planetary and lunar views at say 30° altitude with landscapes at 10 miles from the observer, the latter, he says, "showing precious little colour". This comparison is fallacious because of the high concentration of dust, smoke, and water particles in the lowermost layers of the atmosphere. Thus the low altitude attenuation is vastly more than at 30° even though an equal number of air molecules are encountered in each path.

Colouration by really clean air is remarkably small. In Iceland I have seen a well defined "white cloud" on the horizon which proved to be a sunlit icefield at 100 miles. Twenty times the zenith path air content failed to give any noticeable reddening with such pure air.

H. E. DALL

166 Stockingstone Road,
Luton, Beds.

What the Vikings Feared

Sir:

Referring to your article "Raising Viking Ships" (July), which asked of whom the Vikings were afraid, a possible solution is that, since they were a superstitious race, they feared, not other humans, but some figure of their imagination, such as a sea monster.

JOHN JARVIS-SMITH

Lambes House,
Sutton Valence School, Kent

FIG. 1. *Using phenolic resin foams for insulation of a flat roof (Photo: Bakelite Limited).*

FUTURE USES OF PLASTICS

H. A. COLLINSON

Seven factors have aided the plastics industry in its spectacular growth. A study of these seven indicates the more likely applications for plastics

Next year, 1962, will mark the centenary of the plastics industry—an industry which in 1960 produced and sold in this country 550,000 tons of plastics material and in the United States achieved the record sales figure of nearly 2½ million tons. Such figures, achieved in less than 100 years, pose the questions—"Where has it been used?" and if expansion is to continue at anything like the current rate—" Where are the future uses?"

Just after the last war there were instances of plastics being used for unsuitable purposes, due to shortages of other materials ; but today, with more materials available and more people knowledgeable about plastics and their properties, this unfortunate situation has been eliminated.

In examining the factors that have led to the present wide use of plastics, it may therefore be assumed that the material has a satisfactory performance in its present applications.

A study of the present uses of plastics shows that there are seven major factors, one or more of which have determined the use of these materials in any particular project or field. The seven are listed below :

Factors influencing the use of plastics

1. *New materials.* The development, through continuing research, of new materials having new properties that make new uses possible. This must have applied to all plastics materials at some time in their history. In considering future uses of plastics, the creation of new materials will be of considerable importance.

2. *Reduction in price.* Plastics prices currently exhibit a downward trend, and this is particularly marked in the field of the newer thermoplastics. In the last 10 years the price of polythene has fallen 50% ; the price of P.V.C. has also dropped, though not to the same extent.

These price reductions have been mainly due to lower cost of raw materials from the growing petrochemical industry and the increased production on a large scale of the material itself. This pattern of increased demand, leading to increased production and lower prices, creating an even greater demand, has been most marked in the United States.

There are many examples of new applications resulting from reduced prices, but expansion of the use of polythene in agriculture and horticulture is probably one of the most interesting, since it has taken place in such a short time.

3. *New requirements.* Scientific progress in other industries constantly creates a demand for materials with properties entirely different from those available in traditional materials. These demands can often only be met by plastics, and projects such as nuclear power and the development of space missiles calling for special strength/weight ratios and temperature resistance have provided a significant new outlet.

Mr Collinson is Managing Director of Leicester, Lovell & Co. Ltd., Southampton, and Chairman of the Main Technical Committee of the British Plastics Federation.

4. *Logical development.* No sooner is a plastics material isolated than work commences on its modification by chemical reaction and compounding in order to improve or adjust the performance in a certain direction. This leads to a wide range of materials of differing properties within one chemical group or family—high and low density polythene, plasticised and rigid P.V.C., novolac and resole types of phenolic resins. These development activities are normally directed at a specific end-use, leading to a further increase in demand.

5. *Change in economic condition.* The last war gave a big impetus to the further use of plastics. One of the major factors was the scarcity of traditional materials, particularly those which had to be imported. The use of plastics for purposes which would normally be uneconomic proved to be a mixed blessing, but it undoubtedly demonstrated the effect that changes in price and availability of traditional materials could have on the scope for plastics.

6. *Improvements in fabricating and moulding machinery.* A very good example of this is the development of blow moulding. Basically this process consists of transferring a hollow length of molten thermoplastic into a mould and then blowing it against the sides of the mould. Improvements in the equipment used for this process led to reduction in costs of fabrication and the development of new ranges of sizes and designs. The blow moulded squeeze bottle used for packaging products, ranging from detergents to glue, is now an established feature of modern life.

7. *New physical forms.* Change the physical form of a plastics material and a vista of new uses opens up ; P.V.C. in sheet form is used for garments, decorative coverings and floor tiles ; foam it to many times its original volume and it finds its way into upholstery, acoustic insulation, packaging and floor underlays.

Reinforce a synthetic resin, such as polyester, with glass fibre and the scope of its application widens to include boat construction, transparent glazing sheets and car bodies.

A study of the expansion of uses of plastics over the past decade will show that whilst one of the above factors may have dominated a particular application, some of the other factors have played a significant part. This is especially true of those factors stemming from research and development such as "logical development," "new requirements" and "new physical forms"; and it is the essentially dynamic nature of these factors that provides the thrust and turbulence so characteristic of the industry, and makes it difficult to limit the possible end-uses in the future.

The future

Having established the basic causes leading to new uses of plastics materials, it is now proposed to examine the effect that these various factors are likely to have in the future.

1. *New materials.* From a review of current research activity it can be seen that polymer production and new methods of polymerising dominate the scene. The replacement by fluorine atoms of some or all of the hydrogen atoms in the polythene structure has produced materials of high heat resistance and good weathering properties.

Polycarbonates, with properties not widely different from epoxides and excellent for potting compositions, may soon be available at prices below that of nylon.

It is possible to conceive of polymers from carbon dioxide, and the inorganic field using boron and silicon should not be forgotten. Inorganic polymers, without carbon atoms, will have higher temperature resistance than existing materials.

Polyformaldehyde—a rigid material with a high softening point—has already begun to replace metals in certain applications ; and the development of radiation graft polymers and graft interpolymers demonstrates the possibilities of producing new materials by polymerising one polymer on to another in the same manner as grafting is carried out with trees.

2. *Price.* In considering the future trend of prices it is important to link this with future changes in economic conditions. It is believed that some combination of these two factors will lead to a considerable increase in usage of plastics, both in variety and in quantity.

In the building industry, for example, there is both an upward trend in the initial capital cost of a building and a heavy burden in maintenance costs. In many cases, the deciding factor for or against a particular type of construction is the future cost of maintenance.

With normal building materials increasing in cost, while there is a fall in prices of plastics materials, it is foreseeable that the marginal difference between the two will be outweighed by the advantage of absence of maintenance of the plastics materials.

FIG. 2. *Ford "Levacar"—mach 1. Experimental model uses reinforced plastic mouldings and acrylic glazing (Photo :* Rubber & Plastics Age).

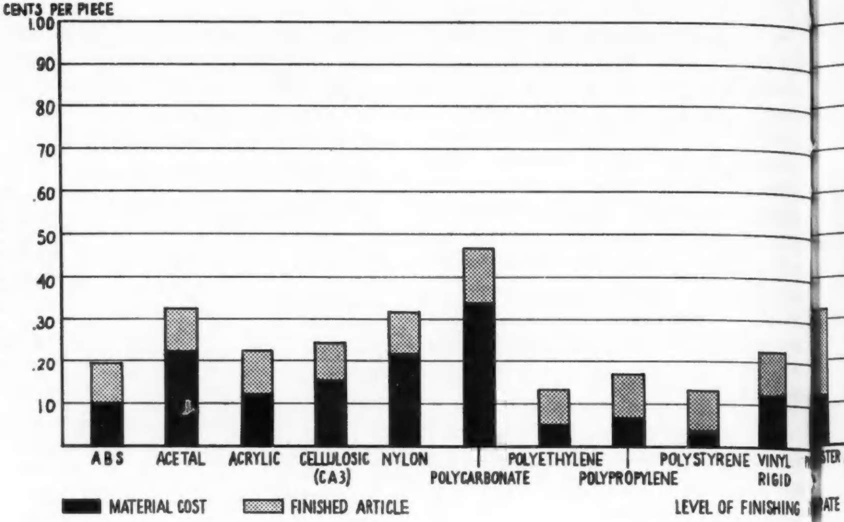


FIG. 3. *Cost of a five cubic inch part fabricated from a range of plastics and metals shows price advantage for plastics. Figures were prepared by Society of Plastics Industry Inc. and refer to U.S. only. Fabricating costs (black) added to material cost (shaded) include a constant injection moulding charge for all plastics except phenolics and polyesters, but vary for the four metals compared. (Photo:* British Plastics.)

A list of the uses of plastics in buildings is already a formidable one, including flooring, roof lighting, piping, electrical fittings and wall coverings, mostly of the non-load-bearing elements. The future will undoubtedly see the acceptance of reinforced plastics in the structure itself.

Past exhibitions such as Wembley and the Festival of Britain have made a considerable impact on building design, providing as they do an opportunity for architects to use new materials and new designs. The presence at the Brussels Exhibition of a substantial volume of plastics materials being used for structural purposes can reasonably be taken to indicate the future of plastics in this field.

The U.S. Society of Plastics Industry recently prepared a chart comparing the cost of a typical five cubic-inch component moulded in metals and plastics. The total cost was broken down into materials, fabricating and finishing, and in all cases the plastics article was cheaper than aluminium, zinc, brass or steel, partly due to the weight advantage of plastics and partly to the absence of finishing costs.

While recognising that there are other functions, such as strength and elasticity to be taken into account, it is clear that in the future plastics must be considered as a possible economic alternative to metals, particularly aluminium and the non-ferrous metals.

New requirements. Since the turn of the century the speed-range for transport vehicles has widened. The gap between a bicycle and the fastest train of 60 years ago must be contrasted with our present day position where manned aircraft have reached speeds of 4,000 m.p.h. This change creates two new requirements ; one for materials able to withstand the high temperatures developed by air friction and the other for means of transport that will fill the void between ground travel by wheels with a limit of 150-200 m.p.h. and air travel.

The development of the hovercraft on its substantial cushion of air and the Ford Levacar supported only a few thousandths of an inch from its rail or bearing surface and using air as a lubricant, make it essential for the materials of construction to have a high strength/weight ratio—a property found in reinforced plastics.

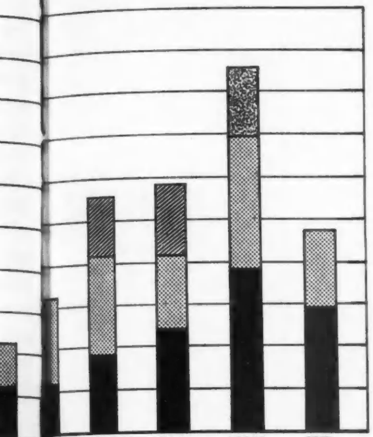
The increasing use of plastics and elastomers in rockets and space missiles and the forecast congestion of these bodies in outer space would seem to point clearly to a future use, the extent of which it is difficult to estimate.

Logical development. Applied research is very highly developed in the plastics industry and many of the future uses will stem from this activity. A little more flexibility, a low water absorption figure, a faster curing cycle—and a modification emerges creating yet another use. Many of these modifications are limited in application, but together they add a substantial addition to the annual tonnage.

The increase in road traffic has created a problem of safer road surfaces. Experimental work has shown the possibilities inherent in epoxide resins to solve this problem, but can these resins be applied in all weathers? At the moment dry conditions are essential, but a modification being developed at present will produce resin/hardener combinations that should not only cure and harden in the wet but actually under water as well.

This applied research also gives impetus to new physical forms, and recent work in cross-linking polyurethane has produced a method whereby a gas is produced during the reaction. This gas eliminates the necessity of adding a blowing agent and gives *in situ* foaming.

Improvements in fabricating and moulding machinery. Reference has been made to a rapid increase in the use of reinforced plastics, both as structural components in buildings and in other fields, such as boats, aircraft and transport vehicles. But there are



two problems with these materials that must be solved. Greater mechanised production giving a faster output at lower cost and a better and more consistent finish from the mould. Both these requirements are essentially mechanical, calling for a new method of impregnating the glass with resin to give a more consistent, homogeneous end product, and this can only be done by eliminating the human element and establishing an automatic production line.

New physical forms. Polystyrene, urethane, vinyl and polythene foams are well established as commercial materials, both in flexible and rigid forms, but many other foams are leaving the laboratory. In the next five years some of these will undoubtedly become established as accepted products.

The present use of foams as cushioning material in furniture and cars will be expanded and an increased amount will go into thermal insulation of buildings and vehicles.

The polyamides, polypropylene, epoxy resins and polytetrafluorethylene are all capable of forming a foamed material, as are the older materials—urea and phenol formaldehyde resins.

If foaming, by changing the physical form, creates new uses then densifying with or without reinforcement will also open up new fields of application, giving from one plastic grouping a range of densities, strengths and properties never before achieved in one material.

FIG. 4. *Applying grit to an Epoxide resin binder during preparation of an experimental strip of anti-skid road surface in Middlesex.* (*Photo :* Leicester, Lovell & Co. Ltd.)

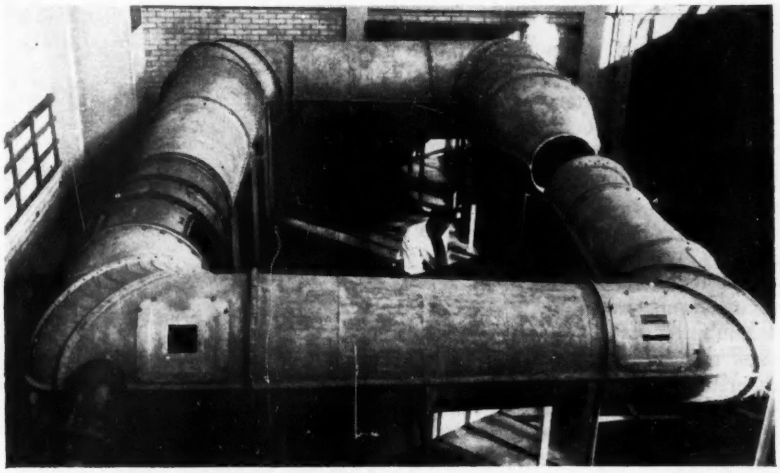


FIG. 5. *This new closed-circuit open jet wind-tunnel, recently installed at Hatfield Technical College, is believed to be the first prefabricated in laminated plastics. It uses a combination of Epoxide resin, glass cloth and resin impregnated glass matt.* (*Photo :* Leicester, Lovell & Co. Ltd.)

Conclusions

No attempt has been made to produce a comprehensive catalogue of the possible future uses of plastics, but this study of the basic causes and factors influencing commercial development of these materials, gives some insight into the width and variety of applications which may be attained.

All plastics materials have two sets of properties, those of formability and those related to the performance of the end product.

Considerable emphasis is laid upon the latter as they are visible and apparent to everyone—electrical properties, durability, low density, good finish, etc. Too little attention is paid to formability, though its significance was early recognised in the generic name of all plastics materials.

There is a need for imaginative design which will give full scope to the plastic nature of plastics, which will break away from the background of traditional materials and processes and will take full advantage of the formability of the raw material, to produce larger single structures of a shape and form not previously known.

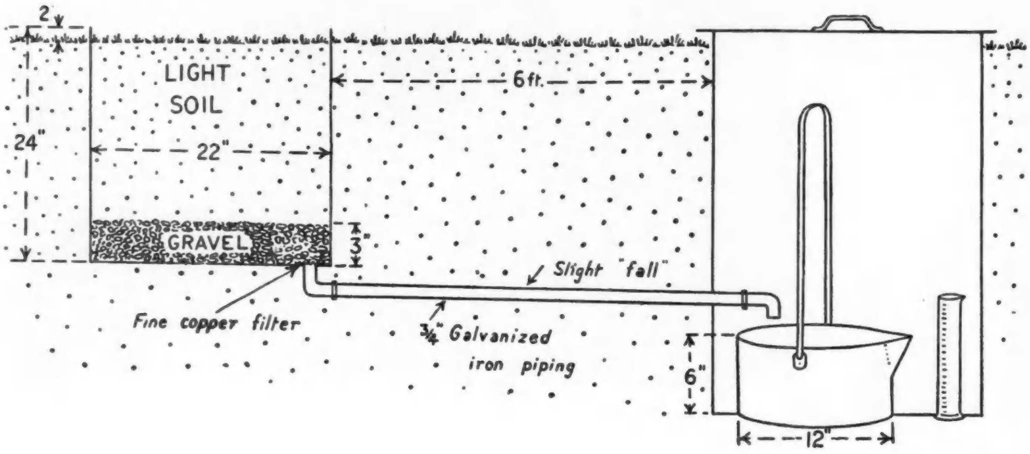


FIG. 1. *Apparatus for the measurement of evapo-transpiration (from F. H. W. Green, The Nature Conservancy, in the* Journal of the Institution of Water Engineers, *August, 1956).*

EXPLOITING BRITAIN'S WATER RESOURCES

S. GREGORY

There are important steps which have yet to be taken before we have an adequate and reliable measure of total water resources. The proposed new authorities could do much for better measurement, and also for making the best use of resources, in the face of competing claims on a limited supply

During the past five years the water resources of Britain have probably received far more attention than in any other period of comparable length. Periodic floods and droughts, with their damage and inconveniences, have always received publicity, but the recent spate of articles and speeches has only partially resulted from such events. Rather there has developed and spread an increasing awareness that despite Britain's reputation for wetness, its water resources require more complete understanding, more considered and organised utilisation, than in the past.

Such discussions have come from a variety of sources—newspapers and government departments, water engineers and industrialists, hydrologists and meteorologists, geographers and professional planners.[1 2 3 4] As a result there is a large and growing body of authoritative publications in relevant fields. However, this wide spread of interests has so far stood in the way of integrated planning and development. Thus the raw data on the available water is obtained by the Meteorological Office, the Surface Water Survey Centre and the Geological Survey ; authority for water supply and pollution problems is vested in the Ministry of Housing and Local Government, although the actual water supply developers are the various statutory undertakings as well as industrialists and agriculturalists ; the Ministry of Agriculture, Fisheries and Food is responsible for drainage and fisheries ; the River Boards have local authority over all uses of water except for water supply and power ; Local Authorities have many and varied interests ; while the voice of the professional is expressed through such societies as the Institution of Water Engineers and the British Waterworks Association.

There are now signs that greater integration may be forthcoming. The Minister of Housing and Local Government has indicated his support for the creation of *one* authority for each catchment area to develop its water resources for *all* uses. The Department of Scientific and Industrial Research has set up a Committee on Hydrological Research, with a membership that is fairly broadly based. Its terms of reference are :

(i) to survey and assess current research relevant to water conservation in the United Kingdom ;
(ii) to identify needs for further research ;

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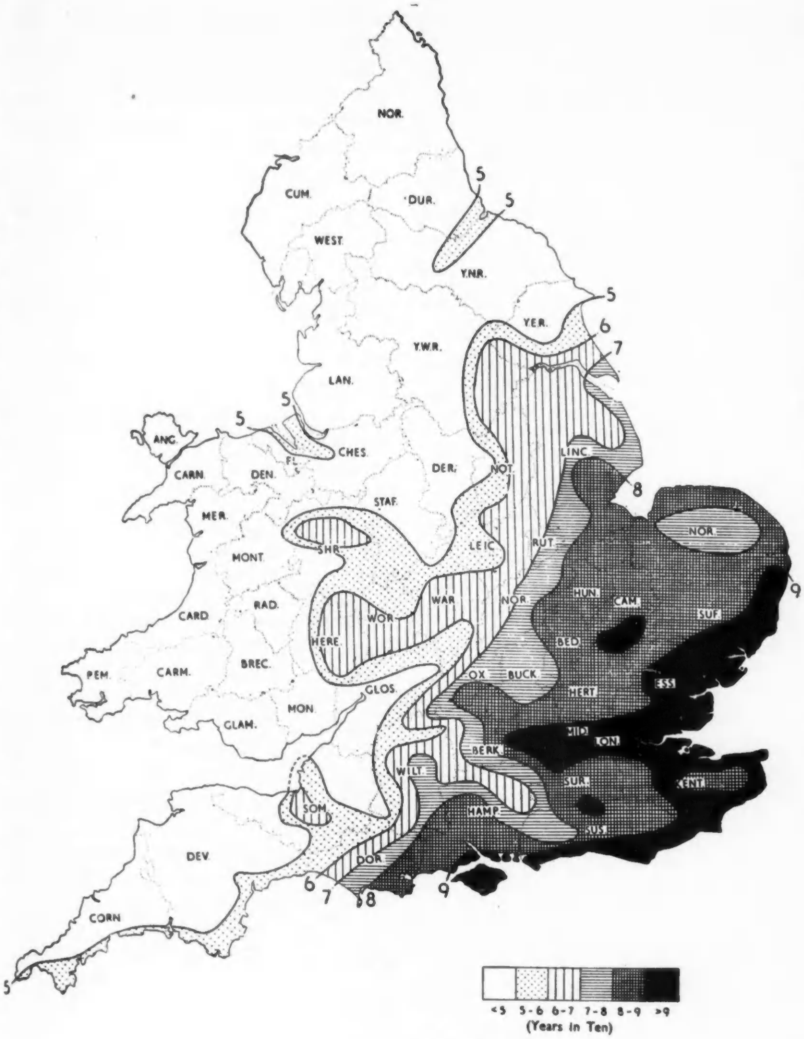

FIG. 2. *The frequency of irrigation need (from* Technical Bulletin No. 4, 1954, *of the Ministry of Agriculture and Fisheries).*

(iii) to allocate priorities ;
(iv) to determine where research should be done and to co-ordinate the work as necessary;
(v) to report from time to time on the progress made.

Measurement of Resources

The basic problem in development of water resources is accurate measurement. In most cases this means measurement of incoming rainfall, losses by evaporation and transpiration, storage of moisture in the soil or in rocks underground, and run-off via the river network.

The problem of detail involves the number of recording stations and their distribution. There are in fact a large number of rainfall stations, totalling between 5,000 and 6,000 in any one year. But the number of continuous records over longer periods, e.g. the 35-year periods of 1881-1915 and 1916-1950 used by the Meteorological Office, totals no more than several hundred at most, while only a handful of stations have continued uninterruptedly since the initiation of the British Rainfall Organisation in 1860.

Furthermore, the majority of the present stations lie at altitudes below 500 ft., and very few are higher than 1,000 ft. above sea level. This relative under-measurement of upland conditions is serious enough, bearing in mind that the greater proportion of Britain's rainfall occurs over the uplands. To make matters worse, these upland stations are most irregularly distributed. There may be 20 to 30 rain-gauges within a catchment area already exploited for its water, while larger areas of the neighbouring hills possess no gauges at all. Thus it is the area of future potential exploitation for which data are negligible or non-existent.

Other facts about the water budget are even fewer. Evaporation records are rare and have not been in existence for very long. Underground storage levels are obviously of interest to water undertakings relying on underground resources, and are measured by them, and also by the Geological Survey. But once again, for large areas there are virtually no current data.

River flow measurements are increasing in number and detail, but many more gauging sites are still required, especially on tributaries. Moreover, the recent date of installation of most existing gauges means that several years must pass before data become at all plentiful.

Apart from the limited availability of these data, their accuracy raises problems. For example, the extent to which rain gauges obtain a representative sample of an area's rainfall has exercised the minds of meteorologists for more than a century. Both the actual site of the gauge and its design are important.[5] Many gauges, especially upland ones, are likely to *under*-record the rainfall of the area, in bad cases by 20% or more. Nevertheless, it is these data, inadequate and unreliable though they sometimes are, that have been used to prepare the maps in the *Climatological Atlas of the British Isles*, and the various studies of specific years of problems in *British Rainfall*, the *Quarterly Journal of the Royal Meteorological Society*, and other journals.

Measurement of evaporation losses also raises problems. Various installa-

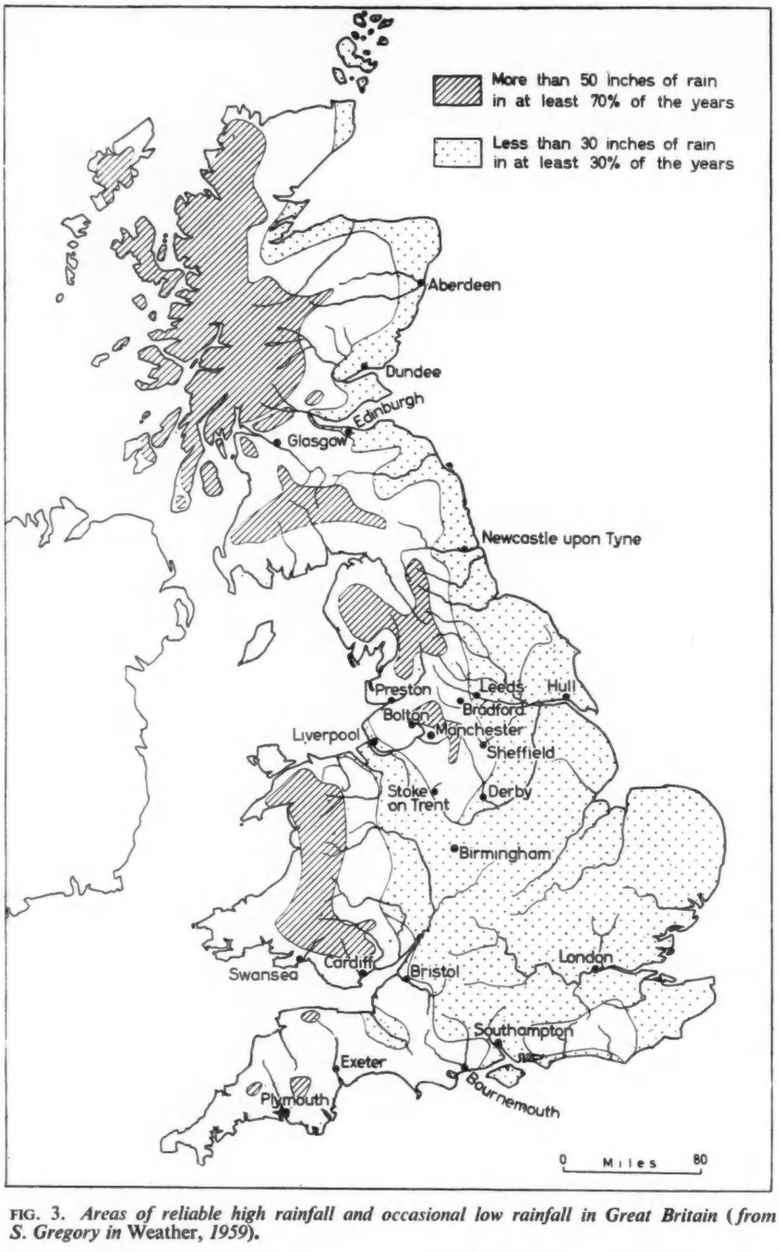

FIG. 3. *Areas of reliable high rainfall and occasional low rainfall in Great Britain (from S. Gregory in* Weather, *1959).*

tions have been used, such as open water tanks, but increasingly measurements are being based on the apparatus shown in Fig. 1.[6] Measurements are made of the amount of water falling on the tank at the left of the diagram, and of the quantity draining from that tank into the bucket on the right, the difference being the amount lost by evaporation and transpiration.

Clearly there are more problems to it than this, especially in the interpretation of results. Also there is disagreement as to the accuracy of this device compared to other installations.

With so few stations available, however, recourse must often be had to theoretical assessment of evaporation loss, based on more easily and more commonly measured conditions such as temperature, radiation, humidity and wind speed. Various theoretical estimates exist, but Penman's is most widely used today under British conditions.[7] These calculations have been applied to the assessment of crop irrigation needs, both at local sites and on a country-wide basis.[8] (Fig. 2.)

River gauging might be expected to be more accurate than the measurement of rainfall and evaporation, but here again methods of measuring river flow vary. Also, frequent surveys of changing cross-river profiles are necessary, while peak-flow flood conditions are difficult to establish.[9]

Despite these errors of measurement, the broad pattern of water resources is relatively clear. For example, if the rainfall of this country be considered not in terms of average values, but in terms of percentage probability of receiving modified amounts of rain, three broad regions may be defined.[10] On the one hand are those areas where less than 30 in. of rain falls at least three years in ten (Fig. 3), so that a deficit of moisture is to be expected in many years. At the other extreme are areas with more than 50 in. of rain at least seven years in ten. Here a surplus of water can always be expected, and it is to these areas that attention must be directed if further exploitation of water resources is to be effectively carried out. In the intervening areas, years of surplus are interspersed with occasional years of deficit, and this raises its own special problems.

Again, on a broad scale Penman's calculations indicate annual evaporation values of between about 14 in. and 18 in. for most of the country.[7] For specific sites or particular development projects, however, the margins of observational error can be significant, and it is frequently found that the amount of water obtained from a catchment is greater than that estimated.

Although this may be useful for water supply, it can be a source of embarrassment in matters of flood control. It would therefore be of value if recording sites for all aspects of water resources could be increased and improved *now*, especially in areas of potential development. Then such development, when it comes, can be based on reliable data.

However, there is a further inexhausti-

ble source of water available to Britain, which only awaits the development of economic plant, i.e. the sea itself. The desalinification of sea water is already a practical proposition in arid coastal areas, while in this country the island of Guernsey has set about installing a sea-water purifying plant.[11] Further developments in this field can be expected, at least in coastal areas, as the costs of conversion to fresh water decrease.

Conflicting Demands

The accurate definition of resources is not the only requirement for efficient exploitation. Thus there is often also a need to resolve conflicting demands. There is a multiplicity of public water undertakings, each responsible for its own sources and distribution system. These are gradually being rationalised, and between September, 1956 and April, 1961, the number of undertakings in England and Wales decreased from over 1,000 to 730. Some 300 authorities were acquired by, or amalgamated into, 86 other existing or newly-created bodies.

Even so, the administrative and development pattern is still intricate, bearing little or no relationship to other administrative areas. The situation in the conurbations shows this clearly (Fig. 4). Furthermore, joint exploitation of resources is still the exception rather than the rule, being limited either to " bulk supply " boards specially created for the purpose, or to such recent developments as are projected along the Severn and the Welsh Dee.

Such co-operative schemes as these have arisen from the desire by several undertakings to exploit the same general upland source of water. Such overlapping interests are not surprising when the role of upland water in supplying the areas of denser population is realised (Fig. 5). The desirability of greater integration was stressed in the Symposium arranged by the Scottish Council (Development and Industry) held in October, 1960, which assessed the water resources of Scotland, and also in the 1961 *Report of the Advisory Committee for Water Resources on Wales*.

Amongst other extractors of water are both industry and agriculture. Industrial abstraction is far greater than that by the water supply undertakings, such water being used for a host of processes, including cooling.

There is a growing body of evidence about the requirements of the major water-using industries. The over-all picture was recently reviewed in some detail by White,[12] while for Britain in particular a succinct summary is available in the *First Report* of the C.A.W.C.'s Sub-committee on the *Growing Demand for Water* (1959).

Agricultural use of water has also increased considerably, especially with the rapid growth of irrigation in the drier areas of the east. This heavy drain on water in the very areas where resources are least is causing a serious problem, which is recognised—though scarcely solved—in the brief *Second Report* (1960), of the above-mentioned C.A.W.C. Sub-committee.

The net result of large-scale abstraction of water by non-statutory bodies is that competition for underground and river water has become intense in many areas. In fact, integrated exploitation is becoming the only possible *modus vivendi*. This is especially so because of the need

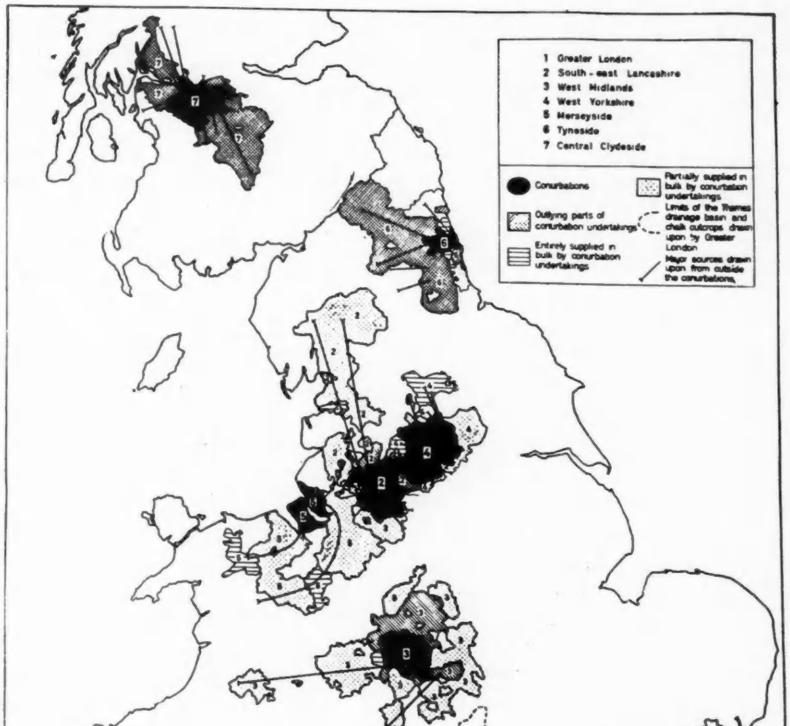

FIG. 4. *How the water supply undertakings are related to the conurbations (from S. Gregory in the* Journal of the Town Planning Institute, 1958).

to dispose of domestic and industrial water after use, when it may be impure, or possibly toxic. But all too often the only means of disposal is into the very rivers from which water may be extracted for further use downstream.

Since 1951 powers have existed to deal with this problem, but their application has been spasmodic and uncertain; presumably positive action must await the forthcoming C.A.W.C. report on Trade Effluents.

Pollution by radioactive materials also impinges on this problem, and a research group of the United Kingdom Atomic Energy Authority is specially concerned with this.[13]

These varied sources of pollution render sections of many of our major rivers unsuitable for some types of water exploitation. Although purification is possible, if expensive, this cannot render these waters suitable for either fishing or recreation. Though neither of these is fundamental in an economic sense, they both represent legitimate demands upon, and uses of, our water resources.

There are two other uses which must be considered because of their local, if not national importance. One is the direct use of water for hydro-electric power generation. In the Highlands of Scotland, at least, this represents the major type of water exploitation and by 1958 it was estimated that about a quarter of the usable water power resources of the Highlands had been developed.

As a result of isolation and distance from large urban areas other types of demand may be negligible for a long while to come. Yet it is here that reliable water surpluses are at a maximum, and the future may well see some competition for these resources. Such competition already exists in the development of water resources for transport, whether via river or canal. Such development normally occurs in drier lowland areas of fairly dense urban settlement, i.e. where local resources are limited and demand heavy. These and other problems are now the responsibility of the Inland Waterways Redevelopment Committee, set up in 1959.

Finally, there is one important activity that can scarcely be looked upon as a *use* of water, but which in some areas represents the major interest in water; namely the need to control the flow of river water to prevent or minimise the danger of flooding. This implies a measure of control which can at times help, and at times hinder, the exploitation of water resources for other purposes.

Problems of Integration

The impetus towards a more unified exploitation of resources has arisen from the competing and conflicting interests of this wide range of activities. These conflicts are locally intensified, either because of excessive urbanisation in areas of limited local resources, or because areas of available surplus are conveniently situated for exploitation for several purposes or by several consuming areas. The problems involved in actual attempts at greater integration are, however, many and varied.

Firstly, there are problems of an essentially administrative nature, involving transfers of authority and powers. These are rooted in conservatism, but they should not prove intractable once the need for changes becomes more widely understood. Even now the basic hydrological data is to be reorganised, with rainfall, run-off and geological material being presented on a catchment area, rather than an administrative basis. Also, hydrological surveys have already been carried out for the Severn and the Great Ouse, and six other such surveys are in progress.

Secondly, there are the technical problems of dovetailing the requirements and activities of various water-using bodies. For example, during periods of floods in the lower courses of a river, should water still be allowed through the turbines for electricity generation and thence out into the river, or should power be decreased and water stored to ease the flood position? Or again, during droughts should river flow be maintained to dilute effluents, maintain fishing and facilitate transport in downstream areas, or should the flow be decreased to ensure that at least a reduced water supply will be available no matter how long the drought lasts?

In a different context there is the question of the sort of vegetation cover that should be encouraged over catchment areas. This will affect not only rates of evaporation[14] and the interception of rainfall, but also the character of the run-off[15] and the degree of erosion. Thus a forested catchment may slow up run-off and ensure a slow release of water; this might be beneficial to water supply yet it can also be detrimental in terms of flooding, under some circumstances.

Such problems as these clearly involve some element of policy-decision, but their solution lies in the hands of the water engineer and his design for exploitation. The extent to which he is likely to be successful in solving them largely depends on how much money is made available, and the degree of priority given to water resource development.

The latter really falls into the third group of problems, which are those of planning policy.[16] These include such decisions as the relative reliance, nationally and locally, to be placed upon underground sources, upland reservoirs and river abstraction. For example, at present virtually all of the Chalk and Triassic aquifers are controlled in terms of water extraction. Moreover, there is an increasing tendency for upland reservoirs to be for purposes of river control, with abstraction downstream, e.g. the Tryweryn scheme in North Wales, rather than for direct reservoir abstraction itself.

Moreover, these decisions must also affect other activities such as upland farming and forestry.[17] In all such policy decisions, however, scientific and technical advice must play a large part. Effective exploitation of Britain's water resources depends on a successful marriage between this advice and the country's social and economic needs.

That such a marriage is being arranged is indicated by a memorandum, dated April 19, 1961, prepared by the Ministry of Housing and Local Government. This outlines proposals on which the Minister is likely to base future legislation dealing with water conservation. After a statement on the need for new measures, the main attention is focused on proposals for some form of water conservation authority, each authority incorporating one or more of the existing river board areas.

Their functions are scheduled to

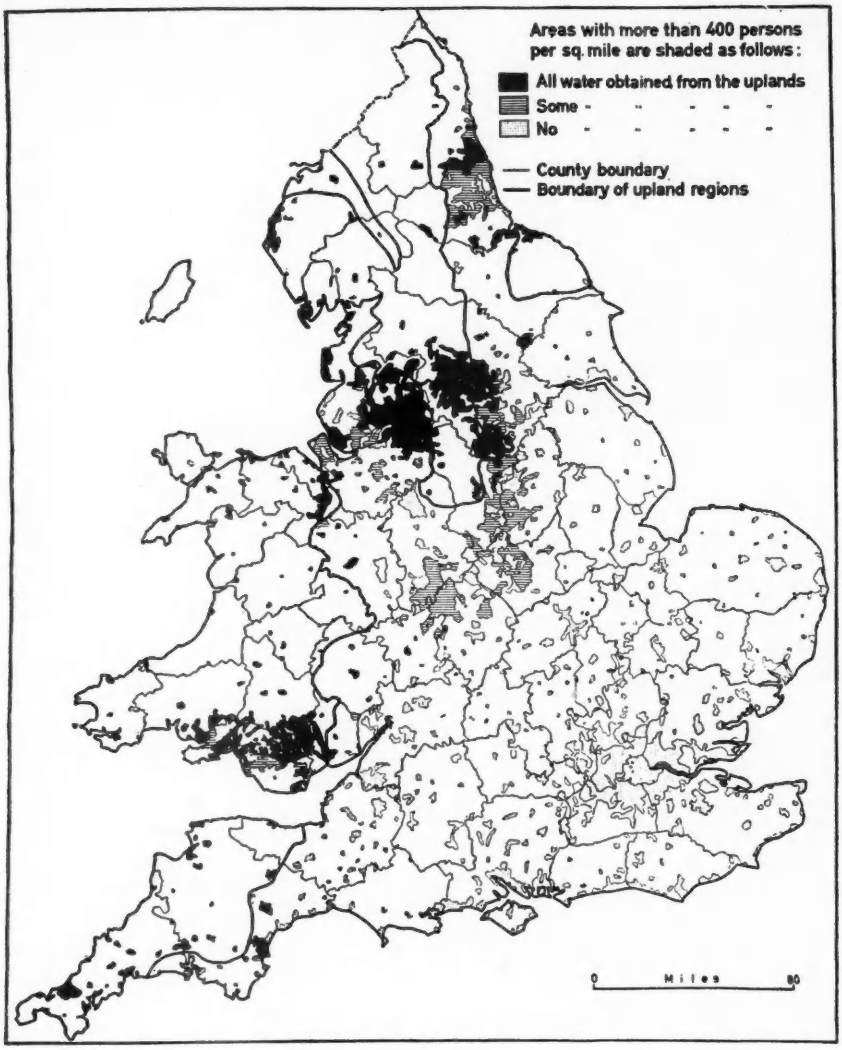

FIG. 5. *The role of the uplands in supplying water to the areas of denser population in England and Wales (from S. Gregory in the* Transactions and Papers of the Institute of British Geographers, 1958).

include hydrological matters ; the preparation of plans for development of resources ; the control, allocation and maintenance of these resources ; and supervision over pollution control, drainage, flood prevention, navigation and fisheries.

Such authorities, assuming that they are established and given the powers at present denied to the River Boards, should be capable of providing that element of integration which is so much required in the exploitation of Britain's water resources.

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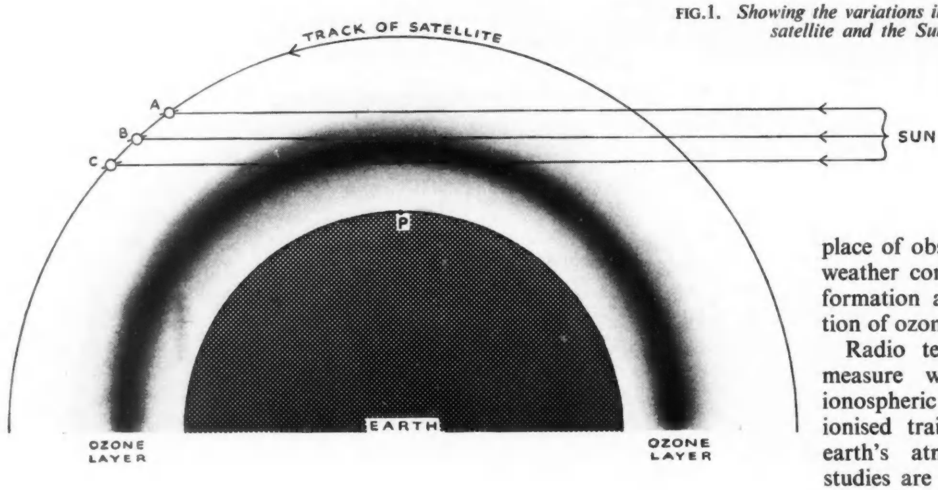
FIG.1. *Showing the variations in the amount of ozone between a satellite and the Sun as the satellite passes into the Earth's shadow.*



MEASURING THE OZONE ABOVE THE EARTH

RONALD FRITH

The second British satellite is planned to carry equipment which, just before passing into the Earth's shadow, and just after passing out of it, will repeatedly measure the absorption of ultra-violet light by ozone in the upper atmosphere.

The earth's atmosphere extends to a very considerable distance from the surface—even at a height of 1,000 km. (600 miles) the atmosphere has a measurable effect on the orbital period of a satellite. Measurements made from satellites, and especially observations of the orbital periods of satellites, are continually adding to our knowledge of the meteorology of these regions.

However, satellites cannot remain in orbit for any appreciable length of time at heights less than 200 km. (at heights less than this a satellite would quickly spiral towards the earth). The first 35 km. or so of the atmosphere can be investigated using balloons—although it has to be recognised that there are large gaps in the network of balloon stations ; but above 35 km. some other method must be used.

Rockets can, of course, reach all levels ; but meteorological soundings must be regular (and rockets are expensive) and world wide (and rocket launching sites are hard to find). Some information about the region above 35 km. can be obtained using ground-based equipment, notably the Dobson ozone spectrophotometer and certain radio techniques. The ozone spectrophotometer measures the total amount of ozone in the atmosphere above the place of observation ; and, in suitable weather conditions, provides some information about the vertical distribution of ozone.

Radio techniques can be used to measure winds either by studying ionospheric drifts or by tracking the ionised trails left by meteors in the earth's atmosphere. These radio studies are of great value ; they have shewn that the upper stratosphere is not the static and featureless region it was, not so long ago, believed to be; it is, especially at levels above about 50 km., a place of tremendous activity, with violent winds and great turbulence ; but they can provide information about winds only in a rather restricted region —from about 80 to 110 km.

The ozone spectrophotometer, which has perhaps been even more valuable, can measure vertical distributions only in cloudless conditions and only up to 40 or 50 km. There is thus still a great deal to be learnt, on a world-wide basis, about the region from the ceiling of balloons to the lower limit of orbiting satellites.

One of the most attractive features of satellites, from a meteorological point of view, is that, if they are placed in suitable orbits, they can readily provide the world-wide coverage required ; but, as already remarked, they cannot remain in orbit at heights less than 200 km. If satellites are to be used for investigations in the region between 35 and 200 km. the observations will have to be made remotely ; the satellite may well be much further from the region of interest than an observer on the ground would be—but the satellite would have the distinct advantage that there would be less air, and usually no cloud, in between.

Satellites have, of course, already been used in this way ; the TIROS series being perhaps the best known example. These satellites take photographs of cloud systems and so they are investigating the atmosphere at levels much lower than 35 km. ; their main

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purpose is to fill in the gaps in the networks of ground observing stations and especially, with TIROS III, to provide early notification of the development of hurricanes over the ocean.

These satellites, and a number of others, also make radiation measurements in a variety of wave bands ; in all cases practically the whole of the radiation measured comes from low down in the earth's atmosphere, or from clouds, or the actual surface. As with the cloud photography, the radiation experiments do not give any information about the region above 35 km.

A team in the British Meteorological Office, led by Dr. K. H. Stewart, is now developing experimental equipment for mounting in a satellite which will measure the ozone concentration at heights up to about 80 km. (mentioned briefly on page 277, July, 1961, issue of DISCOVERY). It is believed that this will be the first satellite experiment designed to investigate the meteorology of this region.

Both oxygen (O_2) and ozone are broken up by ultra-violet light : O_2 being converted into two atoms of oxygen and O_3 into one atom of oxygen and one molecule of O_2. Moreover, when atomic oxygen and O_2 exist together a chemical reaction takes place whereby an atom of oxygen and a molecule of O_2 combine to form a molecule of O_3, ozone.

In any given conditions there will be an equilibrium state (depending on the amount of oxygen present and the intensity of the ultra-violet radiation), in which the rate of destruction of ozone by the absorption of ultra-violet light is exactly equal to the rate of formation of ozone by chemical action.

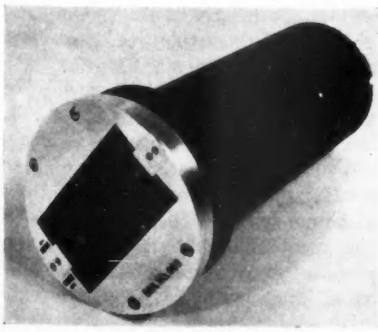

FIG. 2. *The Meteorological Office's ozone scanner to be tested in the second British satellite.*

Such calculations as have been carried out indicate that there should be a maximum in the ozone concentration at round about 30 km., the concentration decreasing to almost zero at a height of about 80 km.

On the other hand at levels below about 25 km. the time constants are very long indeed (being measured in years) and it is unlikely that there ever will be equilibrium. Measurements of ozone concentration from a satellite will help to confirm the calculations of the equilibrium concentrations at high levels ; and, by using ozone as a "tracer" at the levels where the time constant is long, these measurements will perhaps enable something to be learned about the movements of air, both horizontally and vertically.

The Method Used

Let us now turn to the experiment. In Fig. 1 points A, B and C are three positions of a satellite. It is assumed, for simplicity, that the sun is in the plane of the orbit. The intensity of the direct solar radiation reaching the satellite will be steadily reduced as the satellite moves from A to C. This reduction is caused partly by the scattering of light by air, and by any dust present ; but there will also be losses caused by the absorption of light by certain constituents of the atmosphere. In particular ozone absorbs strongly in the region from about 2,400 to 3,400 Å (the near ultra-violet; it is the energy absorbed in this way which causes the ozone molecule to break up into an oxygen molecule and an atom of oxygen).

If the intensity of the direct solar beam in this band is measured and an appropriate allowance made for the loss by scattering (arrived at by measuring the intensity of the direct solar beam in a nearby wave band in which there is no ozone absorption) then the amount of ozone between the satellite and the sun can be computed. This measurement can be made repeatedly as the satellite moves from A to C—a measurement every second corresponding to a height resolution of about 2 km.—and from these measurements the vertical distribution of ozone above the point P can be determined.

There are two complications : first, when the satellite is at B, for instance, the direct solar beam is in the ozone layer through a very considerable horizontal distance ; second, the sun is not, in fact, a point source as it is represented to be in the Figure—it is a disc subtending an angle of about half a degree at the satellite. These complications make it necessary to use an electronic computer for the analysis. Making full allowance for difficulties in interpreting the data, it is estimated that, at levels above 25 to 30 km., the ozone concentrations in layers 5 km. deep can be found with an accuracy of about 25%.

The present intention is to include this experiment in the second British satellite to be put into orbit by the National Aeronautics and Space Administration of the U.S.A., probably in mid-1963. The orbit will have an inclination of about 50° and will be elliptical, with apogee about 1,500 km. and perigee about 300 km. For the ozone experiment a circular orbit as near the earth as possible would be preferred but the satellite will carry two other experiments one of which, a galactic noise experiment, requires some observations from appreciably higher than 1,000 km.

There will be two ozone observations on each orbit—one when the satellite is about to pass into the earth's shadow and the other shortly after it passes out of the earth's shadow. On successive orbits these observations will be at almost the same latitude but at different longitudes, the earth having rotated through about 20° during the period of the orbit. There will be a gradual change in latitude partly due to the change in the position of the sun relative to the earth but mainly to the precession of the orbital plane of the satellite about the earth's axis.

In all, a great part of the earth's surface will be sampled about once every month, only the polar regions being missed. It is hoped to obtain observations for about 12 months.

This sort of experiment could be applied, using other radiation bands, to measure the concentration of other gases, such as water vapour, carbon dioxide and oxygen itself.

PROGRESS IN MICROMINIATURISATION AND MOLECULAR ELECTRONICS

STEPHEN J. ANGELLO

A small computer for every engineer, a domestic one for personal business—these are among the possibilities opened up by revolutionary developments towards low cost and weight, and high reliability. The goal is to make artificial control systems as adaptable as biological systems. But meanwhile, there are problems to be solved . . .

The present trend in electronic circuit construction is towards micro-miniaturisation. The initial pressures for this development came from military requirements for more reliable electronic systems of lower volume and weight. These requirements are especially important in missiles, satellites and aircraft. One pound of satellite payload costs approximately 100 pounds of rocket thrust to achieve an orbit. Development of rockets of higher thrust will not change this basic requirement, because more sophisticated payloads will be demanded as exploration of space proceeds.

In manned aircraft the total number of electronic components has become very large. Fig. 1 shows how the total number of components has grown as each new United States Air Force plane has become operational. The B70 is still in an early stage of development, but it will surely lie on or above this curve extrapolated.

Three general lines of development are evident, all aiming at reducing size and weight and increasing reliability. These are : (1) microminiature components and systematised assembly ; (2) two dimensional (2D) microminiaturisation by thin film components and interconnexions, and (3) molecular or integrated electronics, creating circuit functions in solid substrates.

This article will discuss the advantages and problems of each of these approaches, and assess their place in the development of electronics. Before carrying this out, it will be useful to discuss in more detail the reasons for microminiaturisation, for these are broader than the original impetus and extend beyond military requirements.

Why make microminiature circuits?

One of the major requirements for electronic circuits in general is operational reliability. This is true whether the application is an airborne computer or a television set. In the development of more complex systems we shall be limited by two major factors: (1) reliability and (2) cost. We shall judge the various approaches to microminiaturisation by the potential improvements they make to each of these factors.

Some general improvements in reliability can be obtained merely by making circuits small. It is well known that small structures will withstand high accelerations, because the force on the structure varies directly as the mass. Thus, microminiature tubes have been constructed to be fired from a cannon in a proximity fuse. Similarly, light transistor structures can withstand extreme mechanical shock.

If a circuit is made small enough, it becomes economically feasible to enclose it or a group of functions in a true hermetic seal. Reliability is improved by removing the harmful effects of environment. It also becomes feasible to run comprehensive reliability tests upon a standardised package with typical functions within. Changing the circuit within the package will not require complete repetition of these tests, and so there will be reduced costs for improved reliability.

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The problem of maintaining a microminiature system must also be noted. In all of the schemes proposed, repair must be carried out on a module replacement basis. Either the component packing density is too high to grant access to components, or the module is hermetically sealed, or in the case of molecular electronics, there are no well defined components to fix. Module replacement in the field simplifies maintenance, reduces down time, and transfers repairs to the manufacturer who is tooled to do the job and is staffed with skilled technicians. Whether actual repair is carried out must be decided on the economics of the case.

Attainment of high reliability and low cost will benefit many important civil as well as military applications. Industrial automation requires high reliability. Shutdowns of steel sheet rolling mills and high-rate production lines are extremely costly.

Looking into the future, the possibility of building more complex circuit functions at low cost will result in new products not now feasible. For example, a small computer for every engineer; and even one for home use with memory capacity for personal business. The long-range goal for many control systems must be to make them as adaptable as biological systems. But they will be prohibitively large and expensive unless microminiature functions are available at low cost per unit.

Systematised assembly of microminiature components

Immediate requirements for reduced size and weight can be fulfilled only by one of the microminiature component schemes, for both the 2D and the functional (or molecular) approaches are still in an early stage of research and development.

There are two major approaches to utilising miniature components. These are (*a*) to reduce the size and standardise the shape of conventional components, and (*b*) to redesign components into unconventional forms. These are discussed separately below:

(*a*) Solid state components such as transistors and diodes are essentially very small devices. Most of the physical size is taken by the capsule, which is quite empty inside. The most straightforward approach is to standardise the size and shape of very small packages. The Electrical Industries Association of the U.S.A. has a major committee devoted to accomplishing this. A common procedure is to etch an array of small holes (for example, 0.050 in. diameter) in a photoceram plate. Transistors, diodes, resistors, and capacitors are dropped into the holes with terminals appearing on both sides of the plate. The plate has printed circuits upon it to provide interconnexions. Connexions of components to the printed wiring can be made by bringing each face into contact with the surface of a pool of molten solder. The Thompson-Ramo-Wooldridge Corporation has been a proponent of this technique. Others are Hughes Aircraft Company, and P. R. Mallory and Company. The drawing in Fig. 2 illustrates one of the possible packaging variations due to Hughes.[1]

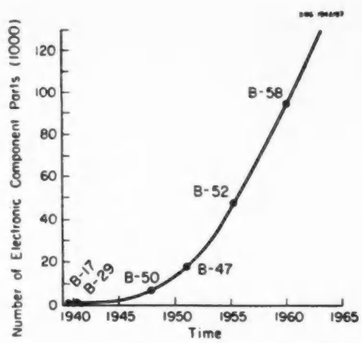


FIG. 1. *Trend of Complexity of Electronics in U.S. Air Force Weapons Systems.*

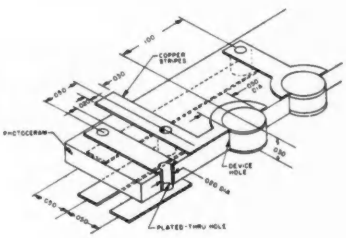
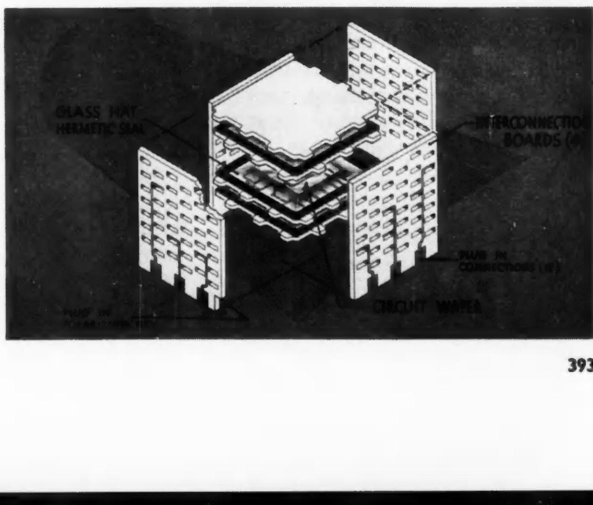


FIG. 2. *Microminiature Component Assembly by Hughes Aircraft Company.*

(*b*) Redesign of components to fit on flat substrates which can be stacked with systematised interconnexions began with the U.S. Navy "Tinkertoy" project.[2] The most recent versions of this avenue of development are the RCA Micromodule[3] and the Sylvania Microminiature Module.[4] Fig. 3 shows an exploded view of the Sylvania scheme. One or more components are built upon a standard size of ceramic substrate (for example, 0.486 × 0.486 × 0.010 in. alumina) with a regular array of terminal points around the periphery. Resistors and capacitors are constructed in intimate contact with the substrate surface for good thermal conduction. In this respect, the micromodule schemes are like the 2D circuits to be described later. Vacuum evaporation and sputtering are useful procedures to form these components.[5] Interconnexion of stacked wafers is carried out by soldering wires or printed circuitry to the wafer terminals. A Sylvania interlocking printed board is shown in Fig. 3. Details of the RCA Micromodule assembly are shown in Fig. 4. More details on these and other variants of the micromodule are given in a review article prepared by editors[6] of *Electronics Magazine*.

The first advantage gained by sys-

FIG. 3. *Exploded View of Sylvania Microminiature Module.*



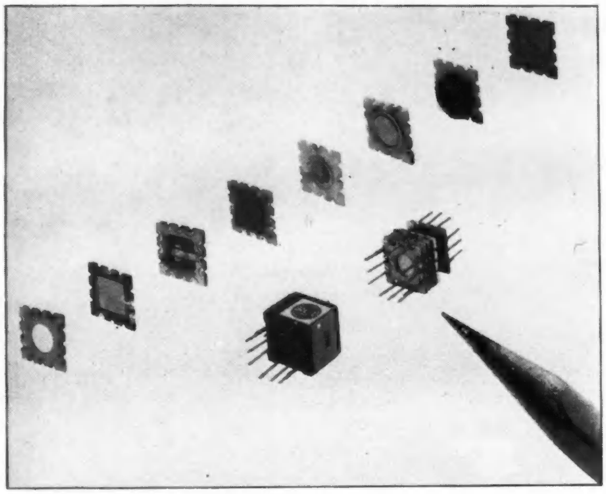


FIG. 4. *Exploded View of Typical RCA Micro-Module.*

tematised assembly of microminiature components is near availability. Within a year, a large selection of standardised components will be available to give circuit designers the flexibility they feel they need. Small mass will favour shock resistance, but the small size may make interconnexions more difficult, resulting in reduced reliability. No data are at hand to give a definite answer yet. No reduction in complexity is achieved, because these are conventional circuits in compressed form. Maintenance must be carried out by determining the economical "throw-away" size of module. High packing density and encapsulation preclude the fixing of joints or replacing of components in the field.

Cost of circuits constructed this way will be high at first, because large volume production of components has not been attained and assembly is by hand. Cost of components will approach the price levels of conventional components, though automatic assembly will reduce production costs. It is unlikely that much capital investment in automatic machinery will be made yet, because of the risk of obsolescence. Tooling commits a manufacturer to a definite scheme. It is too early to tell which one, if any, should be chosen.

Two-dimensional microminiaturisation

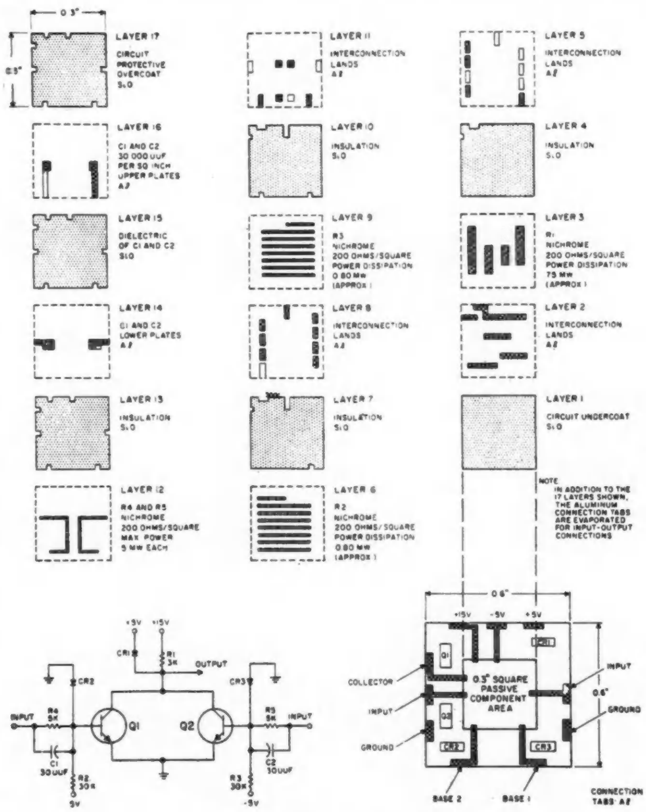
As the name implies, this scheme endeavours to make the thickness dimension of a circuit very small. Pioneer work has been carried on by a group in the Diamond Ordnance Fuze Laboratories of the United States Army.[7]

The aim is to construct a complete circuit by successive evaporation or sputtering of resistors, capacitors, and their interconnexions on a substrate. Sometimes the substrate is a high dielectric material which then serves as the dielectric of the capacitor. Some attempts have been made to evaporate active elements also, but this has not been successful. Diodes and transistors are usually attached to the substrate as unencapsulated chips with lead wires attached.

Fig. 5 shows the steps needed to produce an $\overline{\text{OR}}$ logic function designed by the IBM Company.[8] The various steps in preparation may be followed through the figure.

The 2D scheme is not restricted to digital devices, and Fig. 6 gives an example of a two-stage R-C coupled IF amplifier[9] by the Motorola Company.

This is an appropriate point to discuss a problem which is common to all of the schemes of microminiaturisation, namely, the bulky size and weight of inductors and transformers. The RCA micromodule incorporates wire-wound



ART WORK FOR $\overline{\text{OR}}$ CIRCUIT

FIG. 5. *Evaporation Steps to Produce an IBM Thin Film $\overline{OR}$ Logic Function.*

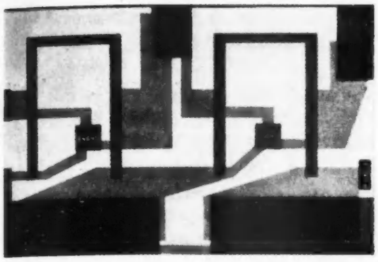


FIG. 6. *A Thin Film RC Coupled I.F. Amplifier by Motorola.*

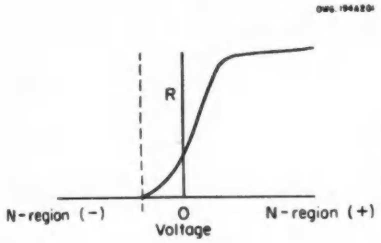


FIG. 7. *Leakage Resistance Vs. Applied Voltage for a P-N Junction.*

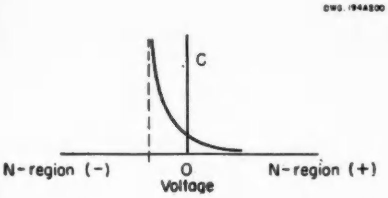


FIG. 8. *Capacitance Vs. Applied Voltage for a P-N Junction.*

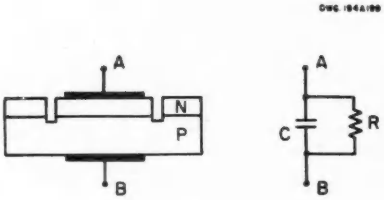


FIG. 9. *Diffused P-N Junction Capacitor with Metallic Connections.*

toroids (*see* Fig. 4) at the sacrifice of one-third of the volume of the whole micromodule. The Motorola 2D circuit (Fig. 6) avoided transformers by using R-C coupling. There are at present three ways to avoid the use of bulky inductors. These are : (1) thin film printed inductors ; (2) circuit simulations by utilising active R-C networks; and (3) device simulations by causing a lagging current phase angle with respect to terminal voltage. Of these three methods the following may be said :

(1) Printed inductors can be used if the inductance is less than about 50 microhenrys/sq. in. Capacitive effects are very serious, and so far this approach has not been successful. (2) R-C networks are quite compatible with 2D procedures and we expect that the studies of active-circuit theory stimulated by this need will result in useful solutions to the problem. (3) Device simulations are appropriate for the molecular or integrated approach and will be discussed in more detail under that heading. Hybrid schemes combining 2D and functional approaches are, of course, possible, and may provide an economical solution to microcircuit requirements until the functional approach is fully developed.

Although the processes of evaporation and sputtering have been known for a long time, the requirements that microcircuits place upon these processes are severe. Further development of process control and economic production procedures is needed. Thin film techniques have the advantage of intimate thermal connexion between component and substrate, but on the other hand, consistent adherence to the substrate is a problem. Potential for reliability and cost reduction are good if all of the problems discussed here can be solved.

Molecular or integrated electronics

The term "molecular electronics" is derived from " molecular engineering", coined by A. von Hipple,[10] by which he described the desirable goal of being able to construct solids which have preassigned physical properties. Molecular electronics seeks to modify the structure of a solid substrate (for example, silicon) to make it capable of performing an electronic function—this is the "functional electronic block". The general object of molecular electronics is to replace the conventional concept of component-component interconnexion with a concept of functional blocks organised into systems. The idea of a "functional block" is an expandable one. It starts with simple passive structures, through multiple diode and transistor structures, progressing to the most sophisticated combinations of electrical, thermal, and mechanical phenomena to perform complete systems.

An important discovery which provides a basic building block for circuits integrated into silicon substrates is the P-N junction.[11] Silicon alloyed with arsenic conducts electric current by electrons or *negative* charges and is N-type. Silicon with boron impurity conducts by electron defects or *positive* charges and is *P-type*. The junction between the two types has a symmetric resistance-applied voltage relation which is shown schematically in Fig. 7. A square centimetre of junction area can have a resistance of 1 megohm.

Concurrently, the junction acts as a non-linear capacitance with applied voltage as depicted schematically in Fig. 8. In practice, a block of N-silicon 0.005 in. thick and $\frac{1}{8}$ in. by $\frac{1}{4}$ in. having about 200 ohm. cm. resistivity is subject to gallium vapour of the order of 1,000°C. Gallium diffuses in as a thin, low-resistivity skin forming a P-N junction.

Fig. 9 shows how a capacitor might be built into the block. The grooves may be etched into the block or sand-blasted with a fine airbrasive gun. This determines the geometry, and hence the capacity of the capacitor. Metal area contacts may be evaporated on the proper regions or may be fused of metal foil. Areas for etched slots and the like are usually defined by the photoresist masking technique.

In this process an organic monomer film is spread thinly over the silicon block. The monomer has the property of polymerising under the influence of ultra-violet light, and becomes then a suitable mask against the etching solution. The areas to be etched are photographed as dark areas on a transparent film plate which is pressed with proper registry against the coated silicon surface.

After exposure, the unpolymerised areas are washed away, leaving the silicon surface to be attacked by the etch. Upon completion of the etch, the polymer mask is removed by a solvent. Areas to be coated by evaporation of metals are defined by metal masks made by the photoresist coating pro-

cess. Holes are etched in the metal mask where metal is to be evaporated on the silicon. Proper registry is also necessary in placing these masks.

Providing a resistor in the block is quite simple, as shown in Fig. 10. Here the resistance of the resistor is defined by the area and skin thickness, and the skin resistivity. Isolation from other circuits is provided by approximately a 100 : 1 ratio of block to skin resistivity. Moreover, if a slight reverse bias voltage can be provided between the skin and the block (greater than 40mV), the junction resistance will provide more isolation.

The two simple "components" may now be integrated into a useful phase-shifting network block depicted in Fig. 11. This function block differs from a conventional component-connected network in several important ways. First, it is not made of discrete components, but the Rs and Cs are distributed. All of the internal connexions are dispensed with, and only the three necessary external connexions remain. Distributed R-C lines are more effective phase shifters than a lumped line with only a few sections. At least six sections would be necessary to approximate the function block of Fig. 11. The second point is then that this function block performs the function with great economy of volume. Hence this circuit is easily made in microminiature form.

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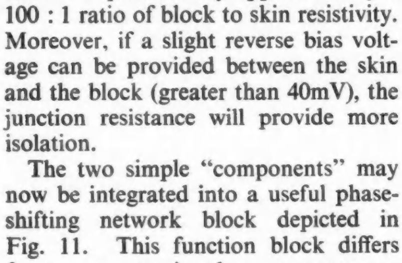

FIG. 10. *Resistor of a Thin Diffused Layer Isolated from the Substrate.*

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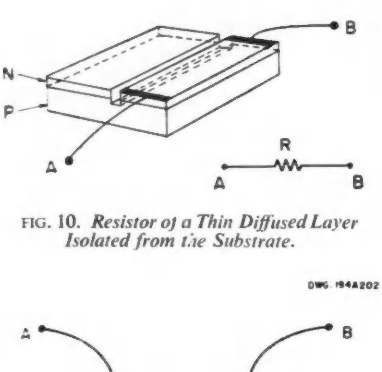

FIG. 11. *Phase Shifting Network with Distributed Resistance and Capacitance.*

A slight extension of this circuit is possible which yields an additional useful property. Fig. 12 is a block like Fig. 11, except that a resistor has been inserted between the common capacitor connexion and terminal C. This results in a bridged-T type of filter which passes all frequencies except a very narrow band. This so-called notch filter[12] can be tuned by varying a bias voltage, because the capacitors are functions of the voltage. A common type of block can be tuned from 0.5 Mc/s to 1.5 Mc/s by varying the bias by several volts.

Another example of a circuit integrated into a silicon substrate is the analog multiplier block shown schematically in Fig. 13. This function block points up two more advantages of the molecular electronic concept. First, to obtain the required accuracy of multiplication for a decade on each input and two decades of the multiplicand, the volt-ampere characteristics of the diodes must be closely alike. The circuit operates on the same principle as a slide rule. In the forward (low resistance) characteristic of the diode the current voltage relation is $i \propto \exp V$, hence, $V \propto \ln i$. Summing the voltages sums the logarithms of the input currents, or the quantities to be multiplied. The current through the diode D_3 is then the antilog or the product of the input quantities.

It has been found that the electrical properties of diodes (and also transistors) made on the same substrate with simultaneous processing are more uniform than can be realised by careful selection of diodes from a large group. Secondly, to obtain accuracy over a wide variation in the surrounding temperature the diodes must all be at the same temperature. Being integrated into the same high thermal conductivity material enables fulfilment of this condition without resorting to a heavy heat sink.

Another way to take advantage of the common thermal connexion is to arrange circuits so that resistance ratios are more important than the absolute values of resistance. The ratio will tend to be constant over a wide ambient temperature range.

Straightforward advantages of single block construction have so far been reviewed. The two illustrations to follow disclose more subtle advantages of the molecular electronics concept. Fig. 14 shows a PNPN structure which acts as a multivibrator in which the thermal connexions among block regions form part of the circuit function. The volt-ampere characteristic of the four-layer structure is shown at two temperatures T_1 and T_2. When voltage is first applied, the characteristic is T_1, and the load line intersects this characteristic at point "a". This is the high resistance "off" condition. Heat dissipation increases the temperature of the block.

When T_2 is reached, the stable point becomes "b" and a pulse of current flows through the four-layer structure. Point "b" represents lower power dissipation than "a"; therefore the block begins to cool towards T_1. Current flows until the T_1 curve is reached.

At this time, the point "b" has moved below the minimum sustaining current for characteristic T_1, and the stable point again is "a". The result is a relaxation oscillation approximating a square wave, with a frequency determined by the thermal time constant of heating and cooling the active region.

Such time constants are longer than those conveniently obtained by electrical parameters. For example, a frequency of 1 c/s would require 0.001 μF of capacity and 10^9 ohms resistance in series. The 10^9 ohms is about four orders of magnitude higher than that which can be conveniently formed in a silicon block. If a convenient value of 10^5 ohms is constructed, a capacity of 10 μF is needed. This is not realisable in a small functional block at this stage of development. One square centimetre will give about 0.001 μF in a P-N junction. Thus, microminiaturisation of a difficult function has been accomplished by utilising thermal and electrical phenomena interacting in a function block.

The second example of interactions within a function block is given by the group of multilayer structures which

show simultaneously a negative resistance and an inductive reactance.[13] Fig. 14 shows a four-layer structure which exhibits negative resistance for a range of currents. If such a structure is biased in the negative resistance region, and a small amplitude AC voltage is applied, the AC current will lag the voltage as if the device were an inductance. The reason is that the current is carried by injected minority electrons or holes which diffuse in the electric field.

The diffusion velocity of minority carriers is much slower than the normal majority carrier current, hence current lags the applied voltage. Details on the diffusion of minority carriers may be found in Reference 11. The most interesting effect is that within the block the same carriers are responsible for the negative resistance as well as the inductance. The result is the possibility of a high Q. In some cases, the effective Q can be high enough to cause oscillation. In any case, the inductive element may be tuned with the capacitor of Fig. 9. All appropriate regions may be integrated into a single block to give a fixed-tuned circuit function.

The major disadvantage of the molecular electronics approach is the lack of flexibility in preliminary circuit design. The present procedure in the development of a functional block is to use semiconductor components as a mock-up to simulate as closely as possible the required block performance. The drawbacks of this approach must be eliminated by developing design theory and procedures. Another disadvantage at this stage of development is that some complicated subsystem functions have yet to be invented. For example, a 40 Mc/s IF amplifier has not been built.

The potential for low-cost functional electronic blocks is considered good because the basic fabrication procedures are similar to those used to make high-quality mesa transistors. Function blocks will eventually be manufactured in multiple and by semi-automatic machinery. The potential for reliability is also good, because of the small, solid block structure and the elimination of many interconnexions. The reliability should approach that of the best mesa and planar transistor.

Major problems and ultimate limits in microminiaturisation

The major problem confronting all schemes of microminiaturisation is heat dissipation and the consequent temperature rise of the modules. Assuming about 50 mW of dissipation per element and convection cooling by air, a packing density of 10^5/cu. ft. would result in about a 100°C temperature rise. There are at present three ways to go about solving the heat dissipation problem: (1) Mount modules carefully with respect to heat flow to avoid hot spots and make maximum utilisation of space.[14] (2) Utilise the heat dissipation to raise the package temperature to the operating point of thermionic tubes. For example, the TIMM concept of microminiaturisation.[15] (3) Develop function blocks which dissipate lower power. The

WHAT THESE MEAN . . .

Sluttering is metal deposition on an electrode in an electrical discharge at below atmospheric pressure. The metal transfers from one electrode to the other.

Redundancy in a circuit means that higher reliability is obtained by building more operative paths than the minimum needed to perform a given function. If one path is destroyed (by component failure, for example) the function can still be performed. Redundancy is not common at present because it is costly and requires space and weight. Microminiaturisation has the potential to make it feasible.

tunnel diode is a possible low-level building element, and the Fairchild Company has constructed very low-level logic functions called Micrologic.[16]

The fundamental limits in packing density are set by the circuit theory of thermodynamics. For instance, the rate at which a circuit dissipates energy in a load reflects back into the circuit power. The higher the frequency, the larger the power in the circuit to conserve energy. Another factor is allowable component value tolerances. Circuits are usually designed for worst conditions, and it will be found that guarantee of proper operation is paid for in power dissipation. The circuit randomness has increased the system entropy. These topics are discussed in detail by J. J. Suran.[17]

Another problem of microminiaturisation is designer education and acceptance. The RCA micromodule, for example, requires a systematised lay-out which is different from conventional circuits. A laboratory manual and training equipment are sold to educate potential users. Two-dimen-

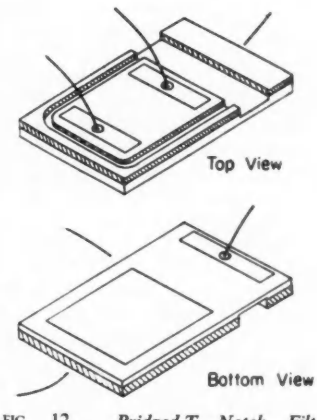

FIG. 12. *Bridged-T Notch Filter Function Block.*

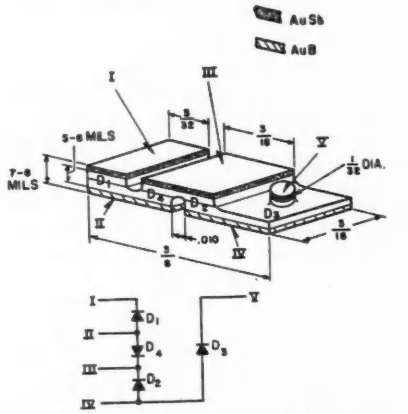

FIG. 13. *Analogue Multiplier/Divider Functional Block.*

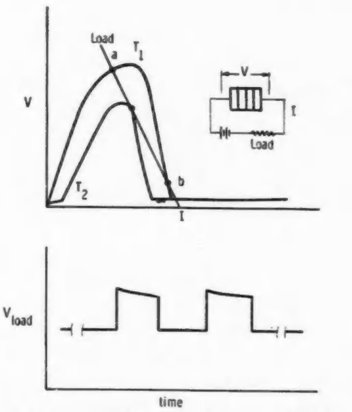

FIG. 14. *PNPN Low Frequency Multivibrator Function Block Utilising Thermal Analogue of Capacitance.*

sional thin film procedures require training even more foreign to the circuit designer. The tools here are vacuum evaporation, metal masks, and thin film topology on ceramic substrates. Molecular electronics requires a successful designer to know circuit theory, device physics, and solid-state fabrication techniques. It appears that a new type of circuit designer must be created who can co-operate with specialists in solid-state technology to construct microsystems.

The major limitation upon the thin film and molecular electronic developments will be placed by our inventiveness and progress in techniques of fabrication. Creativity is needed to utilise the many phenomena known and to be found in solid-state physics, to perform circuit functions. Much effort has been expended upon silicon semiconductor, but there are other semiconductors and other phenomena in magnetic and dielectric materials. Techniques of fabrication are needed to realise in operating from the function concepts of the designer.

The future

The evolutionary development in microminiaturisation which is going on rapidly today will appear as a revolution in electronics when viewed 10 years from now. The size reduction and cost saving potential of microminiaturisation will make it possible to produce redundant and self-adjusting types of systems. The necessary reliability of more complex systems will then be achieved.

New techniques for solid-state system fabrication will be developed. Three recent developments foreshadow those to come. Sputtered tantalum films[18] have important application in thin film circuits. With these films, microfarads of capacity can be supplied in very small volume.

Silicon structures with controlled inhomogeneity can be formed by the epitaxial film technique.[19, 20] Silicon of arbitrary resistivity and either P- or N-type may be grown upon a silicon substrate. Also, more than one layer may be grown with P-N junctions where desired. This technique will be expanded in scope and become common.

Perhaps the most interesting new tool is the use of the electron probe to fabricate microstructures. The electron probe is being used in three ways in present developments. These are: (1) as a machining tool ; (2) as a tool to assist chemical processes : and (3) as a high-resolution viewing device.

Machining uses of the electron probe include the cutting and drilling of small holes. An evaporated nichrome film, for example, can be slotted to a pre-assigned resistance value by the vaporising action of the probe. Because of possible damage to the substrate, the chemical-assist type of use appears more attractive. Photoresist coatings may be polymerised by the beam with higher resolution than one may obtain with ultra-violet light.

Because of the heat dissipation problems discussed earlier, the full microfabrication potential of the electron beam may not be used for a long time to come, but increase in resolution can improve reproducibility of active and passive regions and ensure accurate registration of different regions. This will decrease the "entropy" of the function blocks and reduce heat dissipation.

Another possibility is the formation of silica masks upon solid substrates[21] by the action of the electron beam upon silicone vapour. Techniques of this type are necessary if electronic systems are to be constructed to approach the capability of biological systems.

In conclusion, it may be said that the present development of microelectronics rests upon the discovery of transistor phenomena in 1947. But the future development of microsystems appears even more exciting.

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[14] Cf. reference 5.

[15] Cf. reference 6, p. 90.

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SPACE RESEARCH

(Continued from page 373)

The electron temperature experiment in *Explorer VIII* indicated that the temperature of the electrons generally coincided with the temperature of the uncharged part of the ionospheric gas. Temperatures of both electrons and the uncharged gas of the ionosphere are important to meteorologists.

The **chemical components** of the charged gas in the region under surveillance were also determined. The indications are that oxygen is the predominant gas in the ionosphere up to 650 miles high and that from there outwards hydrogen becomes the leading constituent.

The three back-up experiments connected with the ionospheric studies were directed to delineating the **shape and dimensions of the ionised "halo"** which forms around a satellite as a result of interaction with the ionosphere. This data will permit theoreticians to assess the importance of electrical drag in predicting the orbital life of spacecraft. It has been found that the halo is formed primarily of positive ions in front of the satellite and negative electrons in the wake which extends back to a distance of one satellite radius. The halo round spacecraft distorts radar tracking echoes and their interpretation as well as introducing another variable for aerodynamicists in the calculation of drag. The effects of this recently observed phenomenon can now be better resolved to give improved accuracy in tracking and orbits.

The two remaining experiments in *Explorer VIII* measured the number and size of **micrometeorite particles** impinging on the spacecraft. One equipment tackled this vexed question by an entirely new approach. The other was an expansion of the technique used on *Vanguard III* enabling direct comparison with the rather surprising results obtained then. A picture of the flux of these tiny fragments of material that pass close to the Earth as they orbit the Sun is now emerging.

Taken together, micrometeorite data from *Vanguard III* and *Explorer VIII* amounts to several thousand "events" (impacts by dust particles) as against less than 1000 recorded by all previous rockets and satellites. *Explorer VIII* provided independent witness of a phenomenon first observed by *Vanguard III* and only now released due to the delay in processing the earlier data. This was a peak in the density of dust particles impacting during the three days November 15–17 of 1959 which appeared to coincide with the passing of a major meteor stream.

Micron-sized particles were observed, and there were as many of them hitting the satellite shell during this 70-hour period as struck *Vanguard III* throughout the whole of the remainder of its 78-day life. It is thought that last November Explorer VIII passed through the same meteor stream. Its detectors were however sampling a different size of the material, and other solar effects at the time confused the situation so that it is not yet possible to be quite definite.

In addition to the direct scientific results, *Explorer VIII* yielded an unexpected dividend for future **space research technology.** This was a means of orienting a space vehicle without the use of optics. The payload included several "traps" for ions and electrons and the current flowing from the entering electrified particles gives a fluctuating signal from which the position of the vehicle relative to space can be fixed.

Optics provide an accurate but incomplete satellite-orientation system. When the satellite is hidden by the Earth's shadow from the Sun the most obvious optical reference is removed. The same is true if the Moon or inividual stars are used. The electrified particle traps which, for this purpose can be thought of as angle of attack sensors, are effective throughout the orbit. They could be adapted to point cameras and other directional instruments at the correct angle and to keep them on target. It will probably require a combined system of ion traps and optics to give optimum direction-finding for satellite instruments since the electric sensors cannot be made so accurate as the optical devices.

Testing time for Titov?

It is to be hoped that the Soviet authorities will make available as soon as possible a detailed picture of the medical aspects of Major Titov's spectacular spaceflight 17 times round the Earth on August 6 and 7. An opportunity for this occurs in Paris at the end of this month (Sept. 24-30) when the 2nd International Congress of Space Medicine takes place under the Presidency of Prof R. Grandpierre, Doctor-General of the French Air Health Service.

THE PROGRESS OF SCIENCE

(Continued from page 372)

bark round two sets of carvings gives relative dates as to when the work was done. In the case of the fish, the bark cut away had completely regrown leaving only the outline remaining.

The single Roman capitals, N and A, artistically cut by an early European explorer's hand, showed only partial regrowth of the bark. On a nearby tree a set of three initials roughly cut by a yet more recent hand shows only slight regrowth.

The Maori fish motif occurs on several other trees in the grove, though none of them is as distinct as the first. Symbolic designs of Maori origin also occur. The full significance of the find will take some time to assess.

Scientific summit

This month London is the locale for the triennial meeting of what may be called the "scientific summit", the General Assembly of the International Council of Scientific Unions (ICSU), at which almost all the national science academies of the world are represented. ICSU is the executive parent body of the various international scientific unions concerned with individual sciences and through which world-wide exchange of information, ideas, and proposals are channelled. The Royal Society is host at this year's meeting because the current ICSU president is the British biologist, Sir Rudolph Peters, F.R.S.

It is likely to be an Assembly of outstanding interest. The ICSU constitution is up for revision to make it a more effective body. Several major projects in world-wide scientific co-operation—of which the IGY (sponsored by ICSU) provides the type—are to be taken a step further. Those already in an advanced stage of planning include the International Indian Ocean Expedition (scheduled for 1962-3), the Upper Mantle Project (1962-5) ; also the International Year of the Quiet Sun (1964-5) intended to fill the other half of the picture of which the IGY provided the stormy portion. A three-year International Biological Programme is also expected to be adopted. The Assembly's plenary sessions from Sept. 25-28 will be open meetings.

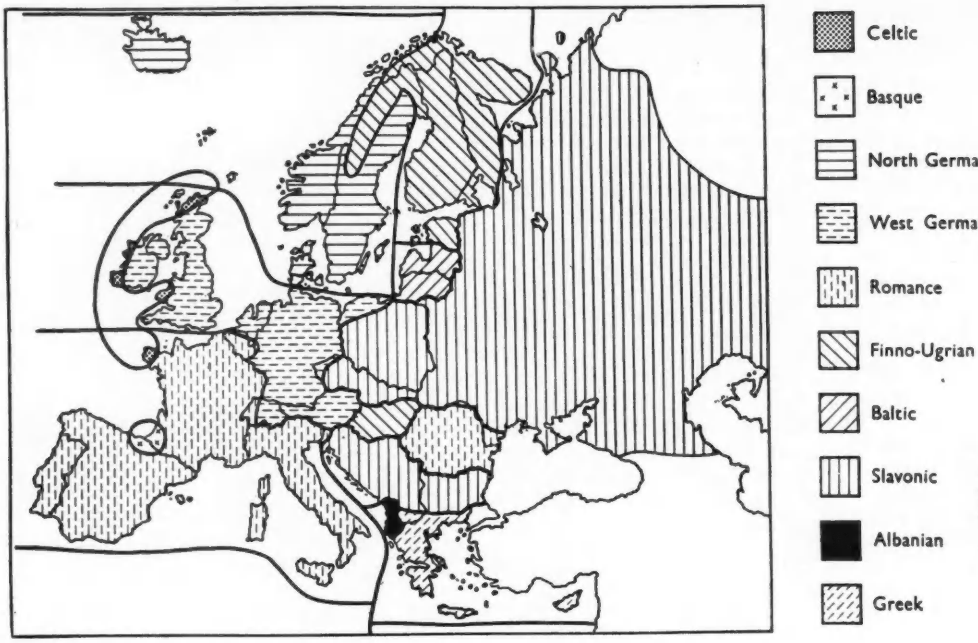

FIG. 1. *The languages of Europe according to their historical relationships. (Photo: L. F. Brosnahan, The Sounds of Language, Heffer, Cambridge.)*

THE INFLUENCE OF GENETICS ON LANGUAGE

L. F. BROSNAHAN

The individual acquires language from his surrounding culture. But heredity influences the structure and function of the vocal organs, and there is some evidence that various racial groups tend to develop language patterns contrary to their cultural traditions.

Human language is basically two-part. On the one hand are the sound units and the sequences and orderings of these units; on the other is the generalised experience which gives it meaning. The two are linked together by association in the brain, making language a symbolic system.

This system is clearly dependent on the structure and functioning of various organs of the human body. The production of the sounds depends on the speech organs—the lungs, larynx, mouth, tongue, teeth, etc., and also on the nerves and the brain centres controlling them. The acquisition of experience depends on the sense organs, and on the complicated brain mechanisms by which raw experience is processed and organised into largely conventional meaning.

As far as known, all sounds used in human language result from the conversion of kinetic energy in an air stream into acoustic energy. The vocal tract from the lungs to the lips and nose lends itself excellently to such a method of sound production. It does not lend itself by any means so readily to, for example, sound production by percussion, and no language seems to use what might be called percussive sounds.

Further, the structure of the vocal tract is such that opening movements of the tongue or lips tend to produce what we call vowel sounds, while closing movements tend to produce consonants. Again, all languages known have representatives of these great classes of vowel sound.

Another widespread characteristic of language is the distinction between two classes of words — corresponding roughly to the verbs and nouns of the grammatical tradition of Europe. The common element of meaning in members of the noun class may be

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taken to be objectness, and that in members of the verb class to be motion. These two groups probably correspond to fundamental classes of man's experience of the outside world—to form and movement.

The advantages of vocal sound for communication between the members of a species has led to the progressive improvement of structures capable of producing and perceiving such sound in many species, among them those ancestral to man. As a result of the genes which he inherited from his pre-human ancestors, man was almost, so to speak, destined to fashion a means of communication out of the substance of vocal sound.

On a very different plane (in the March issue of DISCOVERY), G. H. Wright has drawn attention to ways in which the nature of the vocabulary may be determined in part by the structure of the brain. There appears, for instance, to be a distinct correspondence between the importance assigned by nature to a particular sense —as assessed by the number of nerve channels and the extent of the primary area in the cortex devoted to it—and the frequency in the English vocabulary of words whose meanings are associated with that sense.

The Origin of Differences

If the nature of language is dependent on organic structures in man, are the differences in languages as such dependent on differences in these structures?

This is a question to which the linguist, at any rate in recent years, has given an almost unqualified "No." His answer is buttressed by the argument that a child from one community adopted into a foster-community at an early age will acquire the language of the foster-community, no matter how different from his own, with the same mastery as the children native to it. Nor will he show any trace of "carry-over" from the language of his own community.

Further, the linguist argues, many cases are known in which a whole community has acquired a new language, the language of a conquering people for instance, and within a generation or two has spoken it apparently as naturally as the descendants of its original speakers. It follows from this that an individual or group has the ability to learn—at any rate early in life—the language of any human group. Hence, the linguist continues, it is clear that the differences between languages are not thus based on physical differences between human beings. If they were, such differences would prevent individuals and groups acquiring native-like mastery of the languages of other ethnic groups.

To the linguist, a language is simply part of the culture of a community; it consists of a series of habits—articulatory habits and response habits—and the individual acquires these habits in much the same way as he acquires the habits of eating, of dressing, of respectful behaviour, and so on. Though it is true, the linguist will concede, that there are differences between individuals and groups of men, yet all men have tongues and mouths and brains and nerves, and the minor differences between these organs have no effect on the languages they speak.

There is, of course, a deal of truth in this view; much of language no doubt is part of the culturally transmitted traditions of man, is acquired by the individual and can be borrowed by one group from another. But this is not the whole story. There is the possibility that differences in the vocal organs of human beings are of importance in the development of differences between human languages.

The biologist would regard human language as being a result of the interaction of human heredity and environment. A language is a system of communication developed and dependent on ability to speak. In this ability there are quite clearly hereditary and environmental components; the individual must inherit the potential development of the required organic structures; at the same time he must be given an environment in which this inheritance can express its potential, both for the growth of the structures themselves and for acquisition of the memory and habit patterns characteristic of a language. Just as clearly, differences in either the hereditary or the environmental components will lead to differences in the final result.

The linguist in the past has stressed differences in the latter, almost to the exclusion of those in the former, in explaining the fact that each individual's speech has its own characteristic. "Every speaker's language," says Bloomfield[1], "except for personal factors which we must here ignore, is a composite result of what he has heard other people say." But we recognise the voices of friends and acquaintances not so much by what they say as by how they say it, by the personal quality of the sound, and this quality seems just as likely to derive from the individual character of the speech apparatus as from the individual's experience and environment.

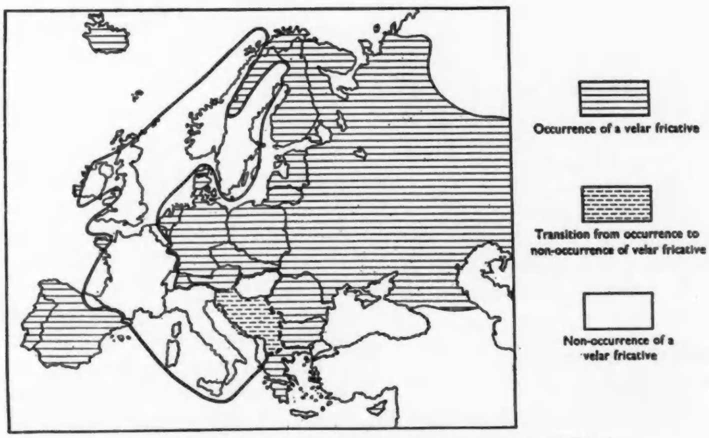

FIG. 2. *The distribution of the velar fricative in Europe. This is the sound represented by* ch *in Scottish* loch *or by* g *in Danish* tage. (*Photo: L. F. Brosnahan,* The Sounds of Language, *Heffer, Cambridge.*)

There are indications that a number of patterns of movement of the organs and soft tissues of the mouth and surrounding region may be inherited. It has been known for some time that there is a strong genetic element in the determination of an individual's voice register; more recently it has been discovered that there are inherited abilities with regard to tongue movement: some individuals are able to roll upwards the lateral edge of the tongue, others cannot; some can fold back the tip, and so on.

In the last few years, information which may be of considerable significance has been provided by the orthodontists. C. F. Ballard[2] has published a number of papers pointing out the widespread difficulty of harmonising clinical experience with the prevailing theories of the value of exercises and conscious effort in the re-education of abnormal posture and behaviour in the mouth. He and a number of colleagues have come to accept that the individual inherits not only an idiotypic posture depending on the size, formation and relative positioning of the organs, but also a series of patterns of motor activity. These patterns are not acquired as a result of learning, but are built into the central nervous system, and form the basis on which the habit patterns, such as those of language, are developed.

At present there are only suggestions as to how this information can be used to forward our understanding of language. Ballard and Bond[3], for instance, wonder to what extent the articulation of a particular language depends on the inherent ability of its speakers to perform patterns of movement, rather than on the learning of specific movements by one generation from another.

Again, it is clear that the nature of language must be such that it is adapted to the wide variety of the structure and functioning of the vocal apparatus which must exist in any community.

Mating Groups and their Languages

The view that differences between the vocal organs of various peoples are responsible for their ability to pronounce "strange" sounds is no doubt a very old one. Its earliest expression in modern science was apparently made by W. Lawrence in his *Lectures in Physiology, Zoology, and the Natural History of Man*, published in 1819. Lawrence gave it as his opinion that the shape of the palate in the Hottentot was one of the factors in their use of the so-called click sounds, i.e., sounds produced by a sucking articulation between the tongue and the palate.

The same view was expressed over a century later by D. M. Beach[4]. With regard to one group of these clicks, he said: "This series seems to be the most difficult for Europeans to acquire. The reason for this seems to be that our tongues are not so thin or sharp-edged as those of the Hottentots . . . The Hottentots and the Bushmen, with their rather canine tongues, can get the exact fit required, and they have the additional advantage that their six upper front teeth make a much wider arc than is the case with most Europeans . . ."

Though the physical anthropology of the vocal apparatus is a much neglected study, a survey of the available literature has revealed adequate evidence of the existence of structural and functional variation in this apparatus among the peoples of the world[5]. Such variation may result partly from the differences in the genetic history of mating groups. Moreover it would seem unreasonable to deny that this variation may lead to group differences in the sound-producing and sound-modulating activity of the vocal tract.

The differences may be very slight and express themselves simply in preferences too weak to be observed in the individual or in the group at any point in time. But a language is handed down from generation to generation and may thus be exposed for quite considerable periods to the influence of such preferences. In these circumstances, gradual change and modification of the articulatory movements for producing the group's language are surely to be expected.

Gradual change in the sound systems of languages is the central fact of historical phonology—but up till the present the linguists have, almost to a man, refused to consider any connexion between such change and the genetics of the people making the sounds.

It is true that there are many complicating and obscuring factors. On the genetic side, the wide range of individual variation and the polymorphic nature of man; on the linguistic side, the necessity of communication within the group, the influence of fashion and education will affect the nature and extent of the sound changes occurring.

However, there is one point which can be tested. If genetic differences between mating groups lead through articulatory preferences to changes in the group of sounds each uses, then such changes should show indications of genetic rather than linguistic or cultural organisation. A few years ago, in a strikingly original paper[6], C. D. Darlington pointed out what he took to be evidence of such genetic organisation, namely, the distribution in Europe of the dental fricatives—the sounds represented by *th* in words such as *thick* and *there*.

Darlington showed that this distribution at the present time—in a peripheral zone comprising Iceland, Western Norway, Denmark, Britain, Spain, Albania and Greece—and the known distribution over the last two thousand years or so—in an intermediate zone comprising Scandinavia, France and Germany, and Italy—were strikingly non-fortuitous and difficult to account for in terms of the histories and relationships of the languages concerned.

These distributions did seem to show, however, a good correlation with the distribution of different frequencies of blood group gene O in the European population. The peripheral zone of present-day occurrence of a dental fricative correlated with the area of O gene frequencies above 65%, the intermediate zone of past occurrence correlated with the area of O gene frequencies between 62% and 65%, while the large area of Europe to the East, in which there is no history of a dental fricative, comprised that part of Europe in which O gene frequencies are generally below 61%.

Darlington concluded that the history and the present-day distribution of the dental fricative reflected the expression of clines of the frequency

of some polygenic complex affecting the articulatory mechanism; such clines, as also those of the frequency of the O gene, manifesting a fundamental genetic organisation of the European population.

A recent attempt[5] to review and develop Darlington's theory has not only tended to confirm a correlation between the dental fricative and blood group gene distributions in the light of more recent information, but has also revealed that a few other sounds or sound features in European languages show distributions which are difficult to account for in terms of language relationships or by any current theory in linguistics. None of these seem to show close correlation with the distribution of any character of known genetic determination, but several show some similarity with the distribution of the dental fricative or with the above zones of O gene frequency: one or more zones running approximately north-south around the periphery of western Europe together with a main area in the east.

This north-south direction of certain zones of similarity of phonetic features is of particular interest, since the closer language relationships in western Europe are mainly east-west: a northern layer of the Scandinavian languages, an intermediate layer of the West Germanic languages, English, Dutch and German, and a southern layer of the Romance languages along the Mediterranean (Fig. 1) Similarities of sound deriving from close common ancestral languages should therefore, and often do, show an east-west distribution in any layer; similarities of sound, on the other hand, which run north-south tend to unite languages of different layers which are thus less closely related (e.g. Fig. 2).

On the face of it these would seem to manifest the working of some factor which is leading to the reorganisation of the geographical distribution of certain speech sounds in western Europe. If, as may be the case in some instances, the reorganised distributions correspond generally with the distribution of genetically based blood-groups (e.g. Figs. 2 & 3), it would not seem too far-fetched to look to the genes for an explanation.

For example, simple accentuation is common to most European languages, but in Swedish, Norwegian, some Danish dialects, Estonian, Lithuanian, and most languages or dialects around the Baltic Sea appear more complex systems of accentuation involving changes of voice pitch within the word. Further, the areal distribution of linguistic features is often restricted.

Over the 3,000 miles from Sierra Leone across Africa to the Nile north of Lake Albert runs a belt, in most places about 400 miles wide, within which practically all languages have a type of consonant with a double occlusion—usually spelled *kp, gb*—a type which is extremely rare elsewhere.

Further, the tonal languages of the world, i.e. those using differences in syllable pitch for word differentiation, seem to be grouped into three great areas: east and south Asia, sub-Saharan Africa, and central America.

If the general theory of genetic influence on the sounds and sound features of languages is valid, these distributions may well reflect genetic characteristics of the populations of the areas concerned. Up to the present, however, save for the blood groups, we have relatively little knowledge of the world distributions of genetically determined features. As information on this topic increases, correlations between linguistic and genetic features may well occur, and such should suggest fascinating and fruitful lines of inquiry both to the linguist and to the geneticist.

There is even the distant possibility, as J. van Ginneken, one of the early protagonists of the theory, pointed out in the twenties, that as the relationships between the two fields become better known, and inferences in either direction become possible, the linguist's precise knowledge of the sound history of some languages during the last two or three thousand years may be of considerable value to the student of human genetics and human evolution.

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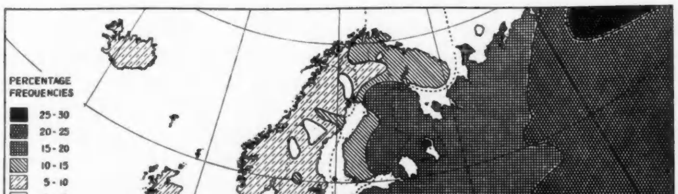

FIG. 3. *The distribution of Blood Group Gene B in Europe. (Photo: A. E. Mourant, A. C. Kopec and K. Komaniewska-Sobczak,* The ABO Blood Groups, *Blackwell, Oxford.)*

NEW LIGHT ON STAMMERING

H. V. HEMERY

Is stammering caused by emotion, or is it physiologically based? The author's successful experience in training suggests the latter.

Probably we are all familiar with the stammerer in action. The embarrassment stammering causes both the stammerer and his audience—especially where both are people of feeling and sensitivity—is self-evident. As the stammerer's speaking difficulty mounts, so does his distress. Each seems to have an exacerbating effect upon the other. Indeed, so closely linked are the emotional disturbance and the vocal blockage that emotional apprehension, or simple nervousness, is generally accepted as the cause of stammering.

My own researches, however, have convinced me that stammering must be physiologically based. This implies that the vocal act itself is at variance with the function necessary for wholly fluent, easy speaking.

Emotional Responses

Emotion was early recognised as an important ıactor which, unless satisfactorily eliminated, would disguise the physiological misuse that was the basic cause of the difficulty. For this reason, after the Second World War, I devised an auditory eliminator. This apparatus comprised a pair of aviator's earphones wired to an electronic device which could be adjusted in pitch and volume to produce a sound tuned to the strength and compass of the stammerer's speaking voice.

When wearing these earphones the stammerer would be deaf to the sound of his own voice and hence his speech action would be freed from emotionally inspired reactions to the sound of his own errors. This left me free to investigate the purely habitual speech function and the effects of postural and other changes upon the act.

Extensive work on these lines, combined with study of the anatomy and physiology of the vocal instrument, confirmed that the stammerer's speech action is basically different from that of the non-stammerer's. It emphasised that until the basis of the action was remedied no amount of voice training could effect a lasting cure. Indeed, it became apparent that the stammerer depended upon all his tricks and dodges, habitual and otherwise, in order to speak at all.

The fact that by the use of a complex, personal repertoire of vocal tricks the stammerer could sometimes speak quite "fluently" despite his fundamental stammer function, demonstrated the soundness of his psychological and physiological make-up. It also led to the coining of the phrase "stammering fluency" to describe the speech action of the stammerer at his fluent best.

When it became clear that the stammerer is a normal individual with a healthy vocal machine but practising bad habits of speech it was logical to conclude that the cure of stammering was an educational matter. Hence the knowledge and experience gained has been applied in practice at Goldsmiths' College and a systematic technique developed whereby hundreds of stammerers have learnt to speak fluently.

Stammering Analysed

Analysis of the act of stammering reveals four distinct levels of action:

1. Fundamental error in voice action adopted, by chance, in early childhood and established as a reflex act at the unconscious levels of motor, that is, muscle performance. The stammerer is quite unaware of the existence of this error and of its immediate effects upon his speaking.
2. The existence of this fundamental stammer function has caused him to invent counter-measures to produce, from unconventional voice action, an effect-in-sound acceptable as "normal" speaking in a young child. These counter-measures were unconsciously adopted and habituated early in the development of speech.
3. Difficulties experienced in speaking as a result of the inadequacy of function at levels 1 and 2, result in awareness of "something amiss with speaking". This naturally prompts the invention of tricks of articulation to dodge the difficulty. Where such consciously introduced dodges prove successful their frequent use leads to habituation. In time they are performed unconsciously.
4. When the standard of speech effected by the first three levels of performance meets the needs of the situation, little or no obvious difficulty is experienced. The stammerer then enjoys "stammering fluency". When the situation calls for a high standard of speech performance so that his self-critical faculty is keener, or when emotional factors upset the balance between error and counter-measure, additional counter-measures become necessary. These tricks and subterfuges are consciously applied by the stammerer himself. They are the antics which others regard as "stammering".

The Potential Stammerer

It will be apparent that if the individual never demands of his speaking function a performance better than that

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in levels 1, 2 and 3, he will be tolerably "fluent" and may possibly escape the label of "stammerer". But because his speaking act is based upon stammer function we may call him a "potential stammerer". He is never a happy speaker. He avoids public speaking at all costs.

If, as a result of promotion in his job or for some other reason, he finds himself called upon to speak at meetings, his increased self-criticism may well bring to him awareness of error, and result in his introducing emotionally inspired action at level 4. The potential stammerer then becomes an "active stammerer", possibly quite late in life.

The individual is unaware of the functioning of many of the muscles he employs for speech and so is unable to improve the function without guidance. Training these muscles in correct function therefore demands of the tutor (i) knowledge of what the muscles are doing wrongly; (ii) knowledge of what they should be doing; and (iii) the ability to induce correct function in the errant muscles of the pupil. This last requirement is met by a technique whereby the desired voice function is learned as an incidental effect of carrying out routine vocal exercises.

By employing this technique and introducing postural improvements, the trainer is soon able to show the pupil how to employ his vocal machine correctly, at an elementary level of performance. In the child stammerer this is all that is necessary because the child will teach himself good habits once he is put on the right road.

The adult stammerer is less malleable. He has a complex stammer function firmly established by long use. Also the speaking skill demanded of him in everyday life is much higher than that expected of a child.

The training process thus requires an initial assessment of the nature of the speaking difficulties and a distinction between habitual, physiological errors and those errors which are of later development and emotionally based.

From this diagnosis is devised a routine whose daily practice induces and consolidates accurate voice function. Correct posture, absence of habitual overaction and overcorrection are factors to be observed. By dividing the speaking act into its simple component movements, each to be practised separately and then conjointly, the trainer introduces the stammerer to the "feel" of ease associated with correct speech action. Repetition of these movements establishes new ear-brain-muscle links in the neural system, whereby the new act becomes accurately reproducible.

Early in his training process the pupil is taught to apply his new technique to speaking the sounds of a short "speech". It is important that he should write the speech himself because he must use his own vocabulary and style. At this stage also he is introduced to the phrase as the unit of speech, and to the need for sustaining his "new" voice throughout the phrase.

The human ear is forgetful and it is easy for the pupil to be satisfied with a progressively lower standard of performance. Frequent reassessment by the tutor is therefore necessary. This is reinforced by group training wherein students speaking before the group are naturally more self-critical than when practising in private.

Speaking from a prepared script leaves the speaker free to concentrate upon an accurate performance, and it is customary for beginners to speak in this way before a large audience shortly after starting their training. But much ground has to be covered before facility in conversational speaking is achieved, because in this the attention is almost wholly centred upon what to say and the most appropriate choice of words.

Progress towards conversational ease is graduated by way of improvising upon a prepared theme, first with the guidance of headline notes, and later with only memorised notes. This is followed by speaking on a given theme, after a few minutes for preparation, and then again as a spontaneous speaker, with no time for preparation. For this training the classes are subdivided into small working groups of students at similar stages of advancement.

As in the child stammerer, it is relatively simple to teach the adult the basic technique of non-stammering speech. The major task with the adult is in dealing with the many "associated habits" he has acquired as a result of his stammering. Thus, certain surroundings, certain people, or certain words may be so closely associated with the distress of stammering that when the conditions are reproduced distress may be experienced. Such an association will tend to pre-condition the individual to stammering action, and he feels he is going to stammer even before he attempts to speak. This last stage of re-education is the hardest of all. It provides a cogent reason for tackling stammering in its earlier stages. Nevertheless, stammering can now be cured by a training technique which has been developed and applied with consistent success during the post-war period.

And on the Continent too . . .

ELECTRONIC EAR FOR THE TREATMENT OF STAMMERING

An « electronic ear » has been presented at the *Salon de l'Enfance* in Paris It has been judged to be excellent for the treatment of stammering and a very useful aid in learning foreign languages.

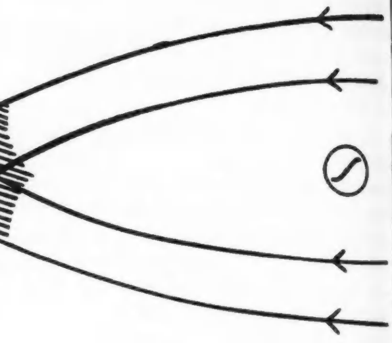
The apparatus consists essentially of two receiving ear-pieces and a microphone The inventor, Dr Alfred Tomatis, has perfected the electronic ear on the basis of the supposition that language disturbances and pronunciation difficulties are, more often than not, the consequence of a deficient uditive perception More precisely, according to Dr Tomatis, the normal subject controls his own voice with a single ear, called the « dominant ear », which sends the signal along the nervous route, to the opposite cerebral hemisphere This in turn, sends the impulses to the muscles governing speech articulation. When there is a reduction of the uditive perception on the part of the dominant ear, the voice-control circuit of the same (ear-brain-specific muscles) passes through both hemispheres instead of through only one, which leads to a variable latent period, ranging from 1/40-1/5 second according to the subject

Dr Tomatis observed that when the latent time ranges from 1/10 to 1/20 second, the subject always stammers, but that this defect can be overcome by regularly exercising the dominant ear in sittings during which the patient speaks into the microphone and hears his own voice amplified by the ear-piece

Two ear-pieces are used at the start when teaching languages, but once the dominant ear has been determined, the student learns more easily if he concentrates perception of the voice solely by the one ear

Reprinted from Rassegna, Vol. xxxviii, No. 1, 1961, Milan.

FIG. 1. *Gas flowing past a galaxy is compressed, and in the shaded region can form a new galaxy by gravitational collapse.*



THE FORMATION OF GALAXIES

D. W. SCIAMA

Are galaxies formed by turbulence in an expanding universe? Are they formed by a birth-process of compression, in the wake of existing galaxies? Due to the longevity of magnetic fields in space, we are likely to learn more on this subject in the next few years.

Recent issues of DISCOVERY have contained articles on "Magnetic Fields in Galaxies," by R. D. Davies (March, 1961) and on "The Character of the Universe," by W. Davidson (May, 1961). In this article I propose to put these two problems together, that is, to discuss the relation between the large-scale structure of the universe and the role of magnetic fields in forming new galaxies. We shall see that each of these topics sheds light on the other.

Some relationship can be expected because galaxies are both *old* and *large*. Our Milky Way, for instance, is at least 5,000 million years old, and perhaps as much as three or four times older still. If we are to understand how the Milky Way was formed we must know what the universe was like in the distant past.

Again, the Milky Way is some 10 kiloparsecs ($3 \cdot 10^{22}$ cm.) across, and may have been much larger at the time it formed (condensed?) out of the pre-galactic gas. We therefore need to know the physical laws that operate over very large distances. It is clear, then, that there is a close relation between the general problems of cosmology and the formation of galaxies.

It is not perhaps so obvious that the same is true for the magnetic fields in galaxies. One of the fascinating aspects of these magnetic fields is that they behave quite differently from magnetic fields in the laboratory. Both of them are induced by electric currents, but in the laboratory these currents die out in a matter of seconds unless they are maintained by batteries, or some other source of electric force. This dying out is due to the *resistance* to which the electric currents are subject. But in interstellar space the resistance is extremely low and the decay-time of a magnetic field is measured in millions of millions of millions of years. The fields described by Dr Davies might thus have been formed at the same time as the galaxies themselves, or even earlier. So again we are involved with the cosmological problem.

The Cosmological Problem

This problem was discussed in detail by Dr Davidson, so we shall give only a brief outline here. The key fact is that the system of galaxies is expanding, that is, every galaxy (or rather cluster of galaxies) is receding from every other one. The velocity of recession is proportional to the distance between the clusters.

This so-called Hubble law is of fundamental importance because it means that every cluster will see this same law of recession relative to itself. The universe is thus uniform on this scale, and our own galaxy is typical rather than central.

Also of fundamental importance is the *rate* at which the universe expands. If clusters of galaxies are unaccelerated,

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then the present observations indicate that about 10,000 million years ago all the clusters were on top of one another. This time, usually known as Hubble's constant, is of the same order as the age of the Milky Way, which reinforces our conjecture that the formation of galaxies cannot be discussed independently of the cosmological problem.

It must be emphasised that our extrapolation into the distant past is illustrative only. In fact we do not know whether the expansion is accelerating, decelerating or remaining constant. Whichever is the case, it might seem that at *some* time in the past the clusters were all crowded together, the actual time depending on the detailed way the rate of expansion changes.

An alternative possibility was pointed out in 1948 by Bondi, Gold and Hoyle. They suggested that the crowding together may never have occurred; indeed that the universe has never looked any different from what it does today, and never will look any different. This "steady state" of the universe is possible despite its expansion, if new material is continually created at a rate which just compensates for the dilution. New clusters of galaxies must be formed as the existing ones recede from one another. In this picture evolution occurs locally, but on a large scale the pattern remains the same.

To decide between this steady state theory and the older evolutionary theories has become the central problem of observational cosmology. It is a very difficult problem because although there are clear-cut differences between the implications of these rival theories, these differences are too small to be reliably detected with existing means of observation.

Dr Davidson mentioned a possible exception to this statement, namely Professor Ryle's recent counts of radio sources. I should like to emphasise that the methods of radio astronomy are still not sufficiently reliable to solve the problem. What is involved is a count of the numbers of radio sources of different measured intensities. From these counts a certain number is extracted.

According to the steady state theory this number should be $-1{\cdot}5$ for the brightest sources and greater (that is, nearer zero) for the faintest sources. The prediction of the evolutionary theories depends on some subsidiary assumptions which the steady-state theory is not free to make. According to the assumptions one chooses, the predicted number can be made to behave in the same way as in the steady-state theory or in the opposite way, that is, decreasing (becoming more negative) for weaker sources.

The first attempt to determine this number observationally was made by Professor Ryle in 1955. His result was -3, which if substantiated would be inconsistent with the steady-state theory. However, in 1958 a second survey was conducted, and the preliminary results showed for two different areas in the sky values of $-2{\cdot}7$ and $-2{\cdot}2$, considerably nearer the steady-state value. In 1959 the complete results of this second survey were published and the number had dropped again to -2.

The fact that such different values could be obtained from the same results shows how uncertain is the reduction of the data. Finally a few months ago Professor Ryle

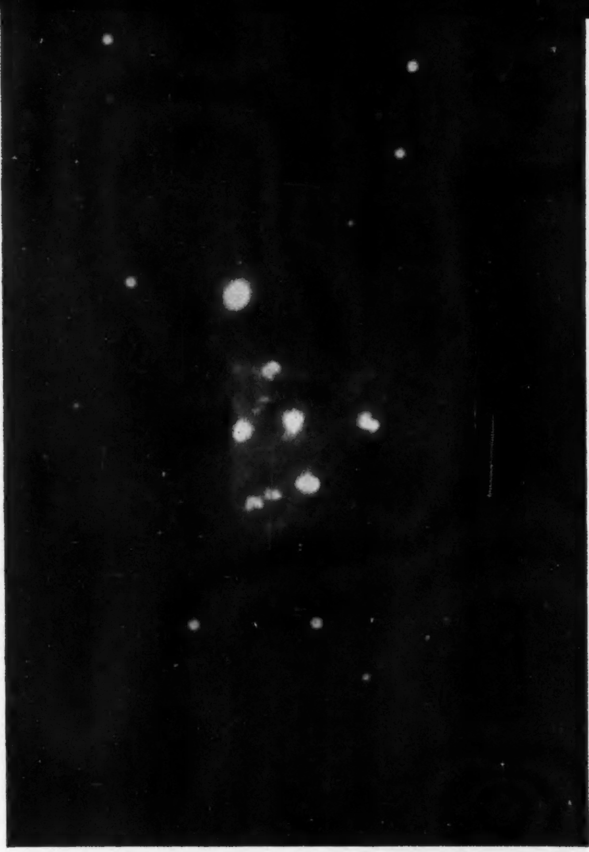


FIG. 2. *These photographs may be demonstrating the formation of new galaxies in the wake of old ones.* (*First published by E. M. and G. R. Burbridge in the "Astrophysical Journal", 130, 1959.*)

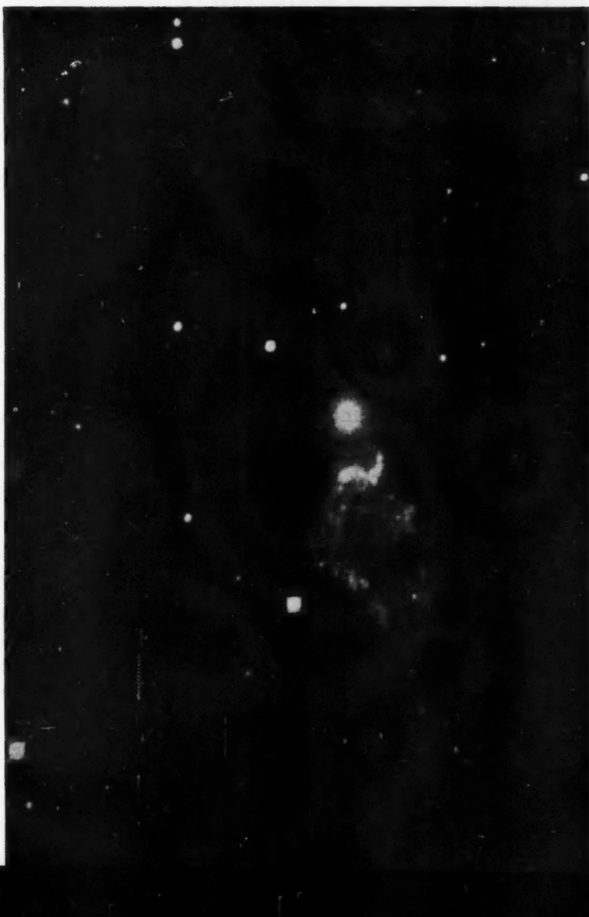


FIG. 3. *A cluster of galaxies.*

announced his latest results, obtained with improved equipment. The value had dropped yet again, this time to $-1{\cdot}8$.

Now most types of error tend to give a spuriously low value to the number sought. It is understandable, therefore, that with each improvement of apparatus and of data-reduction the resulting number has increased. But without an independent check on the errors of the latest work, one cannot be sure that the number will not increase any more. This independent check does not exist. The only comparison one can make is with a survey conducted by Mills in Australia. Mills' result was $-1{\cdot}7$, which, in view of his possible errors, he regarded as not significantly different from $-1{\cdot}5$.

In view of these uncertainties the steady-state and evolutionary theories must be regarded as equally consistent with the observations. New and more-powerful radio telescopes are under construction, but until their results are available we are free to consider the implications of both types of theory for the formation of galaxies and their magnetic fields.

The Formation of Galaxies in Evolutionary Universes

We must first decide what a galaxy is, for our purposes. Which of its properties can be taken as its defining characteristic, from which its other properties can be derived? This basic property appears to be the large concentration of matter inside a galaxy as compared with the concentration in between the galaxies. This difference is considerable; inside a galaxy there is about one hydrogen atom per cubic centimeter, whereas in intergalactic space there is probably only about one hydrogen atom in a hundred litres, which corresponds to a ratio of 100,000 to one.

What has to be explained, then, is the existence in the universe of localised concentrations of matter. If we are lucky we may be able to account not only for the existence of these localised concentrations but also for their main properties. These properties are listed in Table 1.

We must next consider which types of force will be important for our problem. The one type we can be sure of is the gravitational force, which holds a galaxy together as a bound unit. It probably also holds a cluster of galaxies together, although a few astronomers doubt this. Then there are pressure gradient forces which will arise if different parts of the pre-galactic gas are at substantially different temperatures. These forces may be important in practice but little is known about the temperature gradients that may develop, so for simplicity we shall neglect them here. Finally there are magnetic forces; these we discuss later.

Presumably the galaxies did not exist as such at a time when, according to the evolutionary theories, the density of matter throughout the universe was greater than the density within a galaxy. We must therefore try to understand how a localised concentration comes to be formed in an expanding universe at a later time.

A solution to this problem has been proposed by Lemaitre and by Gamow. Their basic idea is that if, for some reason, a region of space temporarily contains far more than the normal number of atoms, then the gravitational attraction of these atoms on one another has some chance of holding the concentration together. An ordinary statistical fluctuation in the number of atoms has far too small an effect, so Gamow has suggested that in addition to its general motion of expansion the gas is swirling about in a random way, that is, it is highly turbulent. This turbulence will be *compressible*, that is, will be accompanied by substantial local changes in density, and where the density is increased gravitation has a chance to stabilise the increase.

Can this idea be developed to the point of accounting for the properties of galaxies listed in Table 1? It was hoped originally that this could be done. For instance, one can place limits on the size of region which can hold itself together gravitationally. For too small a region the gravitational effects will be too weak, and for too large a region there will not be a density increase throughout, but an increase in some parts and a decrease in others. The maximum size of a region is thus determined by the scale of the turbulence. This scale also influences the minimum size, since the turbulence tends to undo its own density increases and the gravitational forces must be strong enough to overcome this tendency.

Everything therefore depends on the characteristics of the turbulence—on its scale and its strength. *These*

characteristics are not determined by the evolutionary theories. There is nothing in general relativity (on which these theories are based) to determine these characteristics. They enter the problem as initial conditions which can be chosen quite arbitrarily. The observed properties of galaxies may help to determine which initial conditions are actually realized in nature, but no explanation is offered for nature's choice. Theories of this type are thus seriously incomplete.

The Formation of Galaxies in the Steady-state Universe

The situation is quite different in a universe which is in a steady state. There is here no question of the formation of galaxies in a system hitherto not containing any. On the contrary any particular galaxy is formed in a universe already filled with them. We now have a new possibility: that these pre-existing galaxies may themselves be responsible for new galaxies being formed. The population of galaxies would then be *self-propagating*.

This would be a possible solution if we could find a set of properties for galaxies which is self-maintaining. If in addition this set is the only *stable* one, we could claim that the steady state theory requires a *unique* set of properties for galaxies. If this set agrees with Table 1 we could then claim that we understood why galaxies have their observed properties.

A complete theory along these lines would have to take into account all the relevant physical factors. This would be a difficult task. In order to make a start I proposed in 1955 a simple model which was still sufficiently complex to lead to a self-determining system. I shall briefly describe this model and then complicate it by introducing magnetic effects.

We begin by fixing our attention on a particular galaxy which is going to act as the parent in a birth-process. Since our aim is to calculate the properties of galaxies we do not yet know anything about this galaxy. Nevertheless, for reasons which will emerge, we assume that it is moving through the intergalactic gas in its neighbourhood. We want to study how this gas is affected by the galaxy's gravitation, so it is more convenient to assume that the galaxy is at rest, and that the gas is streaming past it.

This gas is attracted by the galaxy, and so moves in the manner shown in Fig. 1. As a result of this motion, the gas in the wake of the parent galaxy is compressed, and in the shaded region of the figure its density will be large enough for it to collapse under its own gravitation. Fig. 2 shows two pictures published by the Burbidges in 1959 which they suggest to be examples of this process.

However, this compression does not suffice to ensure that a new galaxy will be formed. What we need is a *permanent* condensation, whereas our collapsing gas will gain enough energy by falling on itself to re-expand to its original size. The collapsing gas must thus lose energy in some way, and the most likely way is by radiating.

Fred Hoyle pointed out to me that a collapsing gas will radiate a substantial fraction of its energy only if its physical properties, in particular the temperature, lie within a certain rather narrow range. These physical

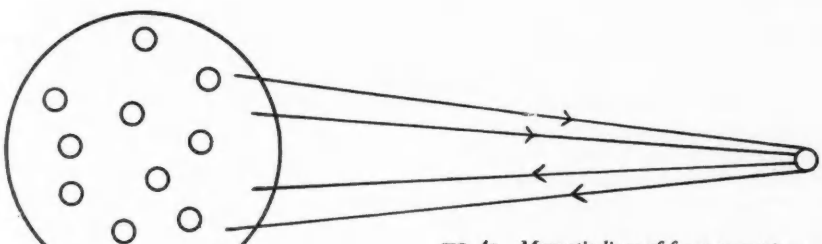
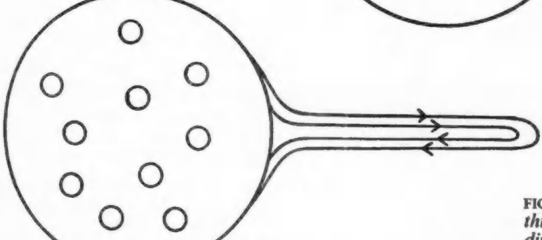


FIG. 4a. *Magnetic lines of force connect an escaping galaxy with its parent cluster. The arrows indicate the direction of the magnetic field.*



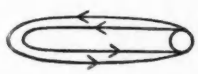


FIG. 4b. *The magnetic lines of force reconnect as shown. The reason for this behaviour is that near the central plane of the wake oppositely directed lines of force are brought close together, and tend to annihilate one another.*

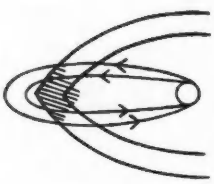


FIG. 4c. *The compressed gas of Fig. 1 falls into the magnetic field in the wake of the parent galaxy. The child galaxy thus contains a magnetic field.*

TABLE I

Average Properties of Galaxies

Mass 10^{44} grams Size 10^{22} centimetres
Rotation Period 10^{8} years
Peculiar Velocity (deviation from exact Hubble law) 10^{7} centimetres per second. Spacing between Galaxies 10^{24} centimetres. Clustering from pairs up to thousands.

properties also determine the mass whose self-gravitation is great enough to cause collapse in the first place.

In this way the mass of a galaxy is determined. The theoretical result is in rough agreement with observation but this is not very significant since our physical model is over-simplified. What is important is getting a definite result at all. It gives us hope that in the steady state theory the detailed contents of the universe can indeed be calculated without the need to make an arbitrary choice of initial conditions.

To complete our account of this simple model we must consider what happens to the child galaxy. This depends on how fast it is receding from its parent. It may escape, in which case a new single galaxy will have been formed. Alternatively it may be captured, so that a double galaxy is formed. We can now contemplate another birth process, since the supply of intergalactic gas has been replenished by the creation of new matter. The new parent now exerts a larger gravitational attraction than did the original single galaxy, and compresses enough material to make two new galaxies. Whether this material in fact forms one large or two normal galaxies depends on the details of each case. Another consequence of the larger mass of the parent is that the children are almost certain to be captured. A triple or quadruple cluster will thus be formed.

This cluster, in its turn, acts as a parent. It will compress enough material to make three or four new galaxies, which will all be captured. With each generation, then, the cluster more or less doubles its size, so we have here a large cluster in the making (Fig. 3). It can be calculated that there will be about a hundred large clusters (of a thousand or more galaxies) within a hundred million light years. The average cluster will be fairly young, and will contain about ten galaxies. These theoretical predictions are not in conflict with observation, but unfortunately no one has yet succeeded in deducing any reliable cluster-statistics directly from counts of galaxies.

There is one final point we must consider as it will play an important part in our discussion of magnetic fields. The galaxies in a cluster are constantly exchanging energy with one another, as a result of their mutual gravitational influence. Occasionally, a galaxy will gain so much energy that it will be able to escape from the cluster, and so become a single galaxy again. This is an important process since it turns out that about half the galaxies which are single at any given moment have in fact escaped from clusters in this way. Incidentally, as a result of their high velocity, these galaxies will be moving through the intergalactic gas—it is this motion which we previously invoked without explanation in our first description of a birth-process.

The Formation of Galactic Magnetic Fields

We shall pursue the problem of the formation of magnetic fields in the context of the steady state theory since this theory enables one to make definite predictions. Dr Davies explained in his article our present ideas about the magnetic field in the Milky Way. However, one of his main statements cannot be accepted,* namely that to explain the radio-emission from the disc of the Milky Way by the synchrotron mechanism requires a magnetic field of $4{\cdot}10^{-5}$ oersted. This would be important, if true, because the field is known observationally to be less than $5{\cdot}10^{-6}$ oersted. However, one cannot determine the magnetic field unless one knows the number of radiating electrons.

Until recently this number was believed to be less than 0·6% of the number of cosmic ray protons of the same energy. This upper limit would imply a magnetic field of only $5{\cdot}10^{-6} - 10^{-5}$ oersted. Moreover, electrons have recently been detected in the primary cosmic ray flux, and in the energy region of importance for radio emission they appear to number 3% of the protons. For this high concentration of electrons, the corresponding magnetic field is only about $4{\cdot}10^{-6}$ oersted which is consistent with the upper limit of $5{\cdot}10^{-6}$.

We now consider the question of the origin of this magnetic field. Hitherto, with one exception, all attempts to answer this question have been local, non-cosmological ones. That is, it is supposed that the magnetic field came into being *after* the Milky Way was formed. These attempts have not produced a clear-cut solution to the problem, and since cosmical magnetic fields are so long-lasting, it is possible that the magnetic field was already present *before* the Milky Way was formed.

Gold and Hoyle have attempted to link the magnetic field with cosmological processes, but their ideas are based on the very specific assumption that the continually created matter appears in a form which confers a very

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**Dr R. D. Davies writes: "If I understand Dr Sciama's argument correctly he claims that the argument for a field of 4×10^{-5} oersted to explain the synchrotron emission was based on his figure for the number of cosmic ray electrons being 0.6% of the number of protons. This was not the figure used in the calculations but a value some three times greater to allow for the effects of the enhanced sunspot activity during the time of the measurements in 1953. This value actually is not much different from the recent measurements and does not greatly alter the figure of 4×10^{-5} oersted obtained. I have based my calculations on the article by Bierman and Davis in 'Zeitshrift fur Astrophysik' published earlier this year.*

"In any case, as I said in my article, there is evidence accumulating to show that a large fraction of the disc component of galactic radio emission comes from objects similar to supernova remnants which are probably regions where much brighter magnetic fields exist locally."

high temperature (about 10^{9}°K) on intergalactic matter. While this appears to be quite possible it seems better not to commit oneself at the outset to such a specific assumption.

The difficulty faced by local theories is to explain how a magnetic field arises where originally there was none. In the steady state theory this type of problem does not arise. One is there concerned to *maintain* a magnetic field, not to create it. Owing to the long lifetime of a magnetic field this is a much easier problem. We shall describe a model which takes advantage of this situation, but again this model is not intended to be a complete representation of all the processes involved.

This time we start by considering a cluster of galaxies instead of a single one. We assume that this cluster is permeated by a magnetic field whose intensity is somewhat less in between the galaxies than it is inside them. We shall have to justify this assumption later by showing that it is a self-propagating state of affairs.

We now follow the fortunes of a galaxy which is expelled from the cluster in the manner already described. What effect does this have on the magnetic field? To answer this question we appeal to a well-known theorem which asserts that when the electrical resistance is very low, the magnetic lines of force are always tied to the same material particles, and so are carried around by them in their motion.

This theorem applies here, and it means that the escaping galaxy drags the magnetic field along with it, maintaining the value of the magnetic field unaltered throughout the region in the wake of the galaxy (Fig 4a). However, in the region close to the central plane of the wake the theorem tends to break down (essentially because oppositely directed lines of force are brought close together). As a result the lines of force reconnect as shown in Fig. 4b, so that the expelled galaxy is in a magnetic field that becomes more or less disconnected from the cluster.

Meanwhile the galaxy is beginning to act as the parent of a new galaxy. The material of this embryonic galaxy gets tied up into the magnetic field (Fig. 4c) and so when it becomes a fully fledged galaxy it will have a magnetic field inside it. If the two galaxies remain bound and grow into a cluster, all the new galaxies will also penetrate the magnetic field. We therefore end up where we began, with a cluster permeated by a magnetic field.

The intensity of this magnetic field will be roughly determined by an equipartition of energy between the magnetic field and the kinetic energy of the galaxies in the cluster. This implies a magnetic field in the range $5 \cdot 10^{-7}$ to $5 \cdot 10^{-6}$ oersted for most clusters. The magnetic field in the galaxies will presumably be a few times larger than the field between the galaxies.

One feature of this process can be tested to some extent, and that is its implication that the magnetic lines of force of the Milky Way stream out into space, rather than forming a closed magnetic "bottle" as is usually supposed. This openness of the magnetic field necessitates a re-discussion of the behaviour of cosmic rays and of the electrons which give rise to synchrotron emission. The key point is that all these particles spend most of their time in between the galaxies where the density of matter is much less than within the galaxies. This picture has the following implications:

(i) Most of the electrons are not secondaries arising from the collision of cosmic ray protons with interstellar gas (as suggested by Dr Davies) but are accelerated at the same time as the protons.

(ii) The energy spectrum of the electrons is the same as that of the protons.

(iii) The spectrum of radio-emission is independent of position in a galaxy, and the same for all galaxies in a cluster.

(iv) The intensity of radio-emission is proportional to the cube of the magnetic field.

Implication (i) has not yet been tested observationally, although it may be soon. There is some preliminary evidence in favour of (ii) and (iii). Implication (iv) means that the magnetic field in the spiral arms, the disc and the halo of the Milky Way are respectively about $4 \cdot 10^{-6}$, $2 \cdot 10^{-6}$ and 10^{-6} oersted. Outside the halo the field could be as great as $5 \cdot 10^{-7}$, as required by the equipartition argument, without conflicting with the radio observations.

It seems almost certain that in the next few years progress in radio astronomy and cosmic ray physics will test our picture rather completely. Whatever the outcome I think it can be claimed that at last cosmology has had an important impact on astrophysics. We owe this to the longevity of cosmical magnetic fields.

THE BOOKSHELF

Structure of the Moon's Surface
By G. Fielder (*Pergamon Press, London, 1961, 266 pp., 50s.*)
Surface of the Moon
By V. A. Firsoff (*Hutchinson, London, 1961, 128 pp., 21s.*)

These two books about the lunar surface come on the heels of awakening interest in its exploration, spurred by recent advances in rocketry. While it is an overstatement to say, with Firsoff's foreword, that "Today the Moon has become priority No. 1 of astronomical investigation", this can be explained, perhaps, by his recognition (loc. cit.) that, "The astronomical world has not fully adjusted itself yet to this new state of affairs."

The two books under review, coming on the heels of Firsoff's earlier book on the *Strange World of the Moon* (Hutchinson, London, 1959) grew up, in fact, in the atmosphere of the lunar section of the British Astronomical Association and are not spiritually unrelated. "There exist," confessed Firsoff in the foreword to his latest book, "some differences of opinion between Gilbert Fielder and myself. On the whole, however, the development of our ideas appears to have been remarkably similar and, being also supported by Patrick Moore, may be said to represent a nascent British school of selenological thought."

This weighty statement should, indeed, lead us to scrutinise with re-doubled care the contents of the new books, and what they portend for the future. Both are limited very largely to a discussion of the Moon's prolific surface markings which both authors interpret in their own way (Firsoff does so, in particular, in Part 3 of his present volume, under the heading *Selenologia Nova*).

This is, in a way, a pity; for what the surface of the Moon actually represents should be regarded as the "boundary conditions" of all internal (thermal and stress) processes, as well as an "impact counter" of external events, which our satellite must have undergone since the days of its formation. In no other sense can an interpretation of the lunar surface possess any meaning.

A lot of valuable scientific work on these subjects has been done in the past decade by Urey in the U.S.A. and Levin in the U.S.S.R. (thermal history of the Moon), MacDonald (stress history), and Opik and Harrison Brown (external impacts); while Shoemaker and other colleagues in the U.S.A. embarked on pioneer geological and stratigraphic studies of the lunar surface, respecting the fact (so often overlooked) that the laws of physics and chemistry must be the same on the Moon as anywhere else.

A perusal of the recent books by both Fielder and Firsoff reveals that much of this fundamental work on lunar research left very little mark on their writings, and few indications that they understood it even if it came to their notice. Instead, the youthful authors limited themselves very largely to a description of the phenomena one can see or photograph on the Moon, which they interpreted qualitatively in their own way.

Yet this constitutes no "selenologia nova", but a time-honoured attitude, the abuse of which in the past led professional astronomers largely to abandon the study of the lunar surface—when it became evident that the available evidence (limited so far to lunar objects greater than about half a kilometre in size) did not permit an unambiguous interpretation of the observed data—at least without a large amount of precise measurements for which the professionals did not have time or the means, and the amateurs the knowledge or patience. It could lend itself, at best, to the formulation of views which could be neither proved nor disproved.

Needless to say, no amount of personal conviction or agreement between kindred spirits can substitute for a lack of objective proof; and it is precisely this attitude which distinguishes an enthusiastic amateur from a real scientist.

In saying so in respect to the books under review, we do not wish to put them both at quite the same level; for Fielder's is not only larger, but also definitely the better of the two. Unlike Firsoff, Fielder is more sparing in expression and more encyclopedic in the knowledge he exhibits; in addition, his book is much better illustrated—largely by photographs which Fielder secured from Pic-du-Midi in 1956 while a research student at the University of Manchester.

ZDENEK KOPAL

Productive Thinking
By Max Wertheimer. *New edition edited by Michael Wertheimer (Tavistock Publications, 302 pp., 28s.).*

The first edition of Max Wertheimer's book was published in 1945, and represents the fruit of seven years' work—lecturing, discussion, and writing—in the United States. It was made memorable by its famous chapter on "Einstein: The Thinking that Led to the Theory of Relativity". Although it was not large, and although its empirical data were not derived from any elaborate series of conventional and "well-made" experiments, it was then, and it remains still, the most striking single contribution made by Gestalt psychology to the problems of reasoning at the human level.

Max Wertheimer is now gone. In this new edition of his book, all the original material has been retained, but virtually a quarter of the book is new. This new material consists of three chapters which had at one time been intended for inclusion in the book. These are (i) *The Bridges Problem*—a fascinating Piaget-like discussion of how thinking goes on when a child is set the apparently simple task of constructing a bridge with ordinary building blocks; (ii) *Plus Three, Minus Three*; and (iii) *The Square of a Binomial.*

In addition there are some half-dozen new appendices. These are, for the most part, fragmentary, but always suggestive and often amusing notes on aspects of the main topic. Finally, there is a bibliography of Max Wertheimer's writings from 1904 onwards, which gives to the book something of the character of a memorial volume, in honour of the most original of the Gestalt exiles from Hitler's Germany.

This is a striking book in a variety of ways, some of them paradoxical. It was written in English in America, but it is a German book. Yet although it is German and profound, it is lively, fresh, and stimulating. It is important; it was, indeed, a portent, but it is not portentous.

It was intended to be revolutionary (even although the Associationist Establishment had already been largely liquidated), but it is most sweetly reasonable. It is rooted in, and concerned about theory, but it is essentially and intentionally practical. It is already an historical document in the development of psychology in the 20th century, but in its lessons for the teacher it is in a sense timeless. Whatever form our theory of thinking may take it is bound to come up against the kind of fact that impressed Wertheimer, and to try to cope with the kind of issue that he regarded as important.

Strictly from the point of view of psychological theory, the new chapters can hardly be said to add anything novel,

although as illustrating Wertheimer's method and the Gestalt point of view, they are even more telling than the old. So far as the educationist and teacher are concerned, they drive home their points with impressive thoroughness.

What are these points? First, that thinking is essentially creative and productive, and even (or perhaps still more) in the early reasoning of the child, is this the case. This is the point to which Wertheimer thinks our psychological attention should be turned, not in the attempt to *explain* creativity, still less to explain it away, but in order to understand it, and to try to determine how the teacher may avoid stunting its growth or stultifying its expression.

Above all this is a book for all who are concerned with teaching, at whatever level from the infant rooms of the primary school to the university. Especially in the lecture rooms and the tutorial rooms of the universities, where arid, semi-articulate, and ill-organised didacticism is all too common, should this be made required reading for the neophyte instructor.

GEORGE SETH

Modern Materials: Advances in Development and Applications. Vol. 2

Edited by Henry H. Hausner (*Academic Press Inc., 1960, 413 pp., 89s. 6d.*)

The second volume in this series maintains the standard set by Volume 1, which was published in 1958. The objective of the series, in the words of the Editor, is to give the non-specialist the benefit of information from the specialist in order to broaden his knowledge of materials. Whether specialist articles of this type can indeed provide such benefit is debatable: much depends on the nature of the presentation and the technical level of the discussion. A basic presentation of the principles of materials science is frequently required before such specialist assessments can be attempted, and this is, of course, just what books of this type cannot give.

Accepting for the moment that the book is directed towards those engineers with a somewhat more enlightened outlook on materials, we must then ask whether the subject matter is well selected, and whether it is presented in a form which engineers can be expected to assimilate.

Authors' estimates of the engineers' appreciation of materials science obviously vary wildly. The treatment of the basic factors of Borides (B. Aronsson) is certainly for specialist consumption by metallurgists, and would leave the average engineer struggling. As a review of fundamental knowledge (with some 200 references) it is, however, first class. Things are a little easier in the article on the fabrication, properties and applications of Borides (R. Steinitz).

The article on Titanium Metallurgy (H. Margolin and J. P. Nielsen) is again just what one looks for in recommending advanced reading to metallurgical students: a most admirable examination of fundamental considerations, but tough going for engineers. In contrast, the articles by C. E. Jackson on Welding Materials, and by D. M. Borcina on Soldering Materials, are absolutely in tune with the aims of the volume. These deal with the practical engineering questions, and also examine the special factors which arise with individual materials; this is exactly what materials engineering is all about.

There are two interesting articles on ceramics: one on ceramics for cutting purposes (W. M. Wheildon) and the other on modern flame-sprayed ceramic coatings (N. N. Ault and W. M. Wheildon). Neither of these subjects has a very extensive literature—certainly not as far as reviews are concerned—and it is refreshing to see original examinations of such subjects rather than re-hashes of well-known material—a device well known to authors and reviewers alike.

The book is completed by an article on Polymer Modified Papers by E. C. Jahn and V. Stannett. Again, the basic principles and the technology are judiciously mixed, and the whole is presented in a form which should be perfectly acceptable to those with a basically engineering outlook.

A. J. KENNEDY

Primates—Comparative Anatomy and Taxonomy: IV Cebidae (Part A)

By W. C. Osman Hill (*Edinburgh: University Press, xxii+523 pp., 189s.*)

It was the realisation of the need to present in a readily accessible form the available information relating to primate structure, behaviour and classification that prompted Dr W. C. Osman Hill to embark upon a series of monographs of which the present volume is the fourth. In each part, data available in the literature are supplemented by extensive original observations that Dr Hill has been able to make on material derived from the London and other zoological gardens.

The first two volumes in the series were concerned with the lemurs, loris and tarsiers. In the third, Dr Hill proceeded to an examination of the marmosets and tamarins (Hapalidae)—these forming the first main subgroup of the New World monkeys (Platyrrhini). The present volume continues with a study of some of the remaining New World monkeys—these being included in the family Cebidae. This family is, in turn, split into six subfamilies (Callicebinae—the titi monkeys; Aotinae—the douroucoulis; Pitheciinae—the saki monkeys; Cebinae—the capuchins; Alouattinae—the howler monkeys; Atelinae—the spider and woolly monkeys). Of these, all except the last two are treated in the present monograph.

At the beginning of each section of the work, there is a systematic account of the main anatomical and taxonomic features of the group in question, corresponding descriptions of its sub-divisions being included subsequently.

Sections of this type, and especially those relating to the bigger taxonomic groups are necessarily eclectic, and the critical reader is conscious of the author's difficulties when, for instance, in dealing with the general characters of the Cebidae, the lack of published information made it necessary to select some genus (in this case *Cebus*) that could be regarded as "centrally-placed" and to prepare from original observations an account that could be used as a basis for the description of the Cebidae in general. But while Dr Hill weaves into this text data relating to other genera within the family, it is evident that often there cannot fail to be difficulty in deciding when a particular feature can be regarded as characteristic of the Cebidae as a whole or when it is merely a variant typical of particular genera or species. Again, when information is sparse, it is difficult to ensure that corresponding sections in different parts of the complete work are in a form that permits ready comparison.

E. H. ASHTON

Even so, in presenting a working picture both of the present state of knowledge in this extensive field and of the areas that remain to be explored, the text can scarcely fail to arouse admiration and gratitude for the enthusiasm that has motivated Dr Hill in initiating and pursuing this task. But in the minds of many, this gratitude may well be tempered by doubt first as to whether, in spite of the considerable original contributions that Dr Hill has made to the field, present-day knowledge is sufficient to form a basis for an undertaking as ambitious as the present work, and secondly whether it is, in fact, possible for an even treatment of so extensive and varied a subject to be within the compass of any single scholar.

E. H. ASHTON

Soviet Research in Fluorine Chemistry: 1949–1956, 1957–1958

Chemistry Collection Series (*Consultants Bureau, $45 and $25.*)

Twenty-five years ago fluorine and its compounds were laboratory curiosities, difficult to obtain and of no commercial interest. In the West the rapid development of fluorine chemistry was certainly brought about by war-time work on the atomic bomb and by related projects for the development of corrosion resistant materials, and it is interesting to compare the Western developments with Russian.

A major impression of this collection is of the strictly utilitarian nature of Russian fluorine chemistry. Much of the physical-inorganic chemistry reports phase studies obviously related to the systems found in industrial processes. The organo-fluorine compounds are often mentioned as being designed for their physiological activity. The Western approach, with its apparent lack of control, certainly produces the most interesting chemistry—what we do not know is whether the Russian way produces the best chemical technology.

Chromatographic and Electrophoretic Techniques

Vol. I, Chromatography, *617 pp., 65s.*
Vol. II, Zone Electrophoresis, *215 pp., 30s.*
Edited by Ivor Smith *(William Heinemann, Medical Books Ltd)*

VOLUME I. CHROMATOGRAPHY

This is the second edition of a book first published in 1958 and reprinted once since. It is a measure of the success of the work that it was considered expedient to expand it from 309 to 617 pages rather than reprint it. To some extent this is a result of newly discovered material becoming available but the scope has been widened to include topics of great importance that are not so new.

VOLUME II. ZONE ELECTROPHORESIS

The method known as ionophoresis or electrophoresis has been extant for a long time, first as a means by which charged particles are caused to move towards one or the other of two electrodes on a microscope stage, then as a means for separating macromolecules in solution by observation of refractive index gradients in the Tiselius apparatus, and lastly as zone electrophoresis. This book deals entirely with the latter, which may be defined as the method of separating mixtures into zones or bands by subjecting them to an electric field maintained in some medium stabilised geometrically in space. Paper, starch gel, cellulose acetate, glass beads, gelatin or agar gel, impregnated with buffer, may comprise such a medium. Depending as it does on comparatively simple apparatus and procedure, zone electrophoresis has opened up a large field of analytical separation of particular interest to the clinical chemist.

It is against this background that we must examine the work under review. Differing from some other books on this subject and its ally, chromatography, the chapters, with one exception, each deal with a separate facet of method. The nine authors have taken considerable pains to give detailed instructions for carrying out the various procedures.

The book will appeal to students but also inform the sophisticated worker.

TUDOR

The Biology of Stentor

By Vance Tartar (*Pergamon Press, x+413 pp. Frontispiece+99 figs., 75s.*)

There are some groups of animals which the general biologist, unless he happens to develop a taste for them, need not know much about: oligochaetes, for instance. There are others he neglects at his peril because in one way or another they contain the material on which his best contemporaries are testing their ideas.

It is now plain that the ciliates belong to this latter class. Their structure, life-histories, genetics, their extraordinary means of reproduction and their apparently unique mating systems are in themselves interesting, and their interest has been brilliantly disclosed in the last few decades by men of exceptional originality of mind.

All approaches to ciliate studies have been made easier by the successful development, since 1950, of an intelligible system of classification. Among students of ciliate morphogenetics, and especially as an experimentalist, Dr Vance Tartar, of the University of Washington, is already known as one of the most distinguished.

His book is bound to receive attention not only from protozoologists but from all who are interested in the wider study of development processes. They will be rewarded.

Dr Tartar does not disguise his affection for *Stentor*. In some ways it is not, as it happens, quite the ideal animal he would like everyone to believe. Its structure is rather specialised. Its infraciliature is peculiar and not well understood. Its micronuclei are so tiny they are hardly ever seen, and it seems that they are inactive except at division and conjugation. The latter process is so rare that the attentive student is lucky to see it more than two or three times in a decade. Autogamy is unknown.

It is necessary, before Dr Tartar sweeps us off our feet, to hold on to the fact that *Stentor* is not a centrally placed, generalised, typical ciliate. It is doubtful how much that is known of it could be extended to other members of its class. What it can do, for some unexplained reason, is recover from types of cutting experiment which would be fatal to almost any other organism of its size. And it lives well in the laboratory.

These facts have long been known and experimental investigations of *Stentor* have been going on for over 75 years. Through the great mass of information which has accumulated in that time Dr Tartar conducts his readers with a skilful attention to detail which never obscures the thread of his narrative.

There are a few weaknesses. The description of fine structure is very difficult to follow and it is not helped by a confused drawing, unmethodically labelled. As we now have (thanks to Prof. J. O. Corliss) a sound and economical terminology to describe the oral structures of ciliates, it is a pity that Dr Tartar decided to invent one of his own.

It is maddening that a man who can write so well as he and can hold attention through pages and pages of analysis and illustration should sometimes be overcome by the feeling that his clear, low-key, respectable style ought to be enlivened by an outburst of hoop-di-doodle.

> "A satisfactory elucidation of the intimate material basis of the elaboration of cell differentiations is rendered promising in regard to *Stentor* by the fact that several treatments inhibit oral anlagen formation, presumably by affecting separate, essential aspects of a complex process."

This in fact is not hoop-di-doodle: it is Ph.D.'s honky tonk.

But the blemishes are restricted. Mostly we have here a fine, clear, critical account of all that touches the experimental analysis of a single genus. Dr Tartar knows his subject so well that he can reach out for just the right illustration, exhibit it in detail, and then pass smoothly on to the next point without apparently disturbing the smooth and lucid flow of his writing.

R. S. J. HAWES

Physics and Archaeology

By M. J. Aitken *(Interscience Publishers: New York and London, 1961, 181 + x pp., 50 figures and xxviii plates in text, 53s.)*

The past few decades have seen a gradual systematic interweaving of the natural sciences into archaeological research. Now for the first time we are given an account of this collaborative work in the field of the physical sciences, developing new techniques for specific needs as well as expanding the range of geophysics. This book is by a physicist who, on the staff of the Laboratory for Archaeology and the History of Art at Oxford, has conducted much of the field work he discusses, and has developed some of the equipment, notably the proton magnetometer.

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dehydrated food

Drying food to preserve it is a technique of considerable antiquity, inevitably so in a world of seasonal food supply. Not that early examples of preserved food were to everyone's taste. There are still some primitive people who prefer a dish of well-rotted fish when there is no fresh food to be had; but they are a minority.

The earliest records of food drying go back to the Sumerians in 3300 B.C. Sun drying was used then, and continued to be used solely, until towards the end of the 18th century when stove and tunnel drying were introduced. But survival was always the prime motive, and while the quality of the dried foods was distinctive—and sometimes interesting—it did not always approximate to that of the fresh food from which it was prepared.

Other means of preserving food have been developed of course—pickling, curing, canning, etc.—and have their own virtues, but they result again in quite distinctive food products.

With quick-freezing there was a major breakthrough—as it were—to preserved food with the quality of fresh food. Now dehydration is coming forward again with new concepts, which give it greater potential to compete with fresh food on its merits, and so to be complementary to quick-freezing. Much of the spadework of this new approach has been carried out by such people as Ede, Marshall and Flosdorf. Unilever are already active in this work, in which success will depend not only on technical advances in method—spraydrying, freezedrying, airdrying, etc.—but equally on a knowledge of breed or strain characteristics, of growth behaviour, of pre-treatment of the fresh food and post-treatment of the dehydrated food.

In Unilever Research, then, Graham, Dow, Evans, Taylor and Withers are actively investigating all these related problems of food dehydration—basic and applied.

UNILEVER RESEARCH

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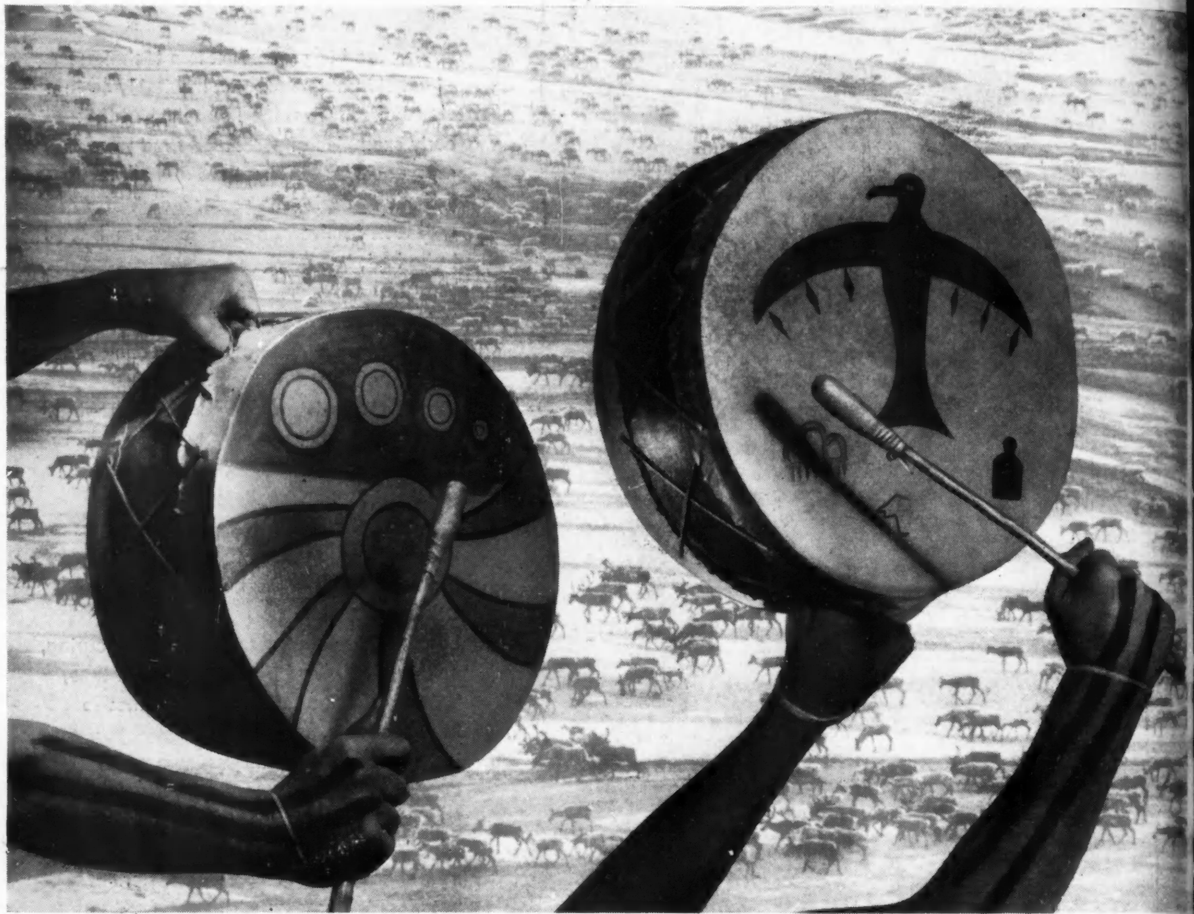
Drums (non-returnable) along the Athabaska



PRI73H

Under the midnight sun of Canada's far North-West, a line of barges creeps into Yellowknife—a gold-mining settlement on the desolate shore of a great lake. Their load—cyanide in drums—is prosaic, perhaps; but it has completed an adventurous journey that started 10,000 miles away at an I.C.I. factory in England: by sea across the Atlantic and through the Panama Canal to Canada's Pacific coast; down-river by barge, overland again for many a rugged mile, down-river once more to the waters of the lake itself.

Such odysseys are not uncommon for I.C.I. chemicals, and least of all for I.C.I. cyanide. Known for 50 years as the key for unlocking gold and silver from their ores, it is used almost everywhere these precious metals are mined—in the Australian deserts, in the rolling hills of Southern India, in the mountains of Colombia and the uplands of Fiji. And, like so many I.C.I. chemicals, it is no stranger to the engineering industries of Europe. Cyanide case-hardening salts from I.C.I., as well as degreasing solvents and metal pre-treatments, play a part in the production of everything from hypodermic needles to agricultural machinery.

The influence of I.C.I. research and production is felt today in every corner of the globe

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